UNITED NATIONS

GENERAL ASSEMBLY

Distr.
GENERAL

A/AC.105/574*
12 May 1994

ORIGINAL: ENGLISH

COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE
Thirty-seventh session
Vienna, 6-17 June 1994

SCIENTIFIC AND TECHNICAL PRESENTATIONS TO THE SCIENTIFIC AND TECHNICAL SUBCOMMITTEE AT ITS THIRTY-FIRST SESSION

Report by the Secretariat

1. During the thirty-first session of the Scientific and Technical Subcommittee, the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU) and the International Astronautical Federation (IAF), in liaison with Member States, organized a symposium on the theme "Space applications for disaster prevention, warning, mitigation and relief". The symposium was organized in accordance with the recommendation of the Subcommittee at its thirtieth session (A/AC.105/543, paras. 110-111), which was subsequently endorsed by the Committee on the Peaceful Uses of Outer Space at its thirty-sixth session 1/ and by the General Assembly in its resolution 48/39 of 10 December 1993.

2. The symposium was the tenth to be organized by COSPAR and IAF during the annual sessions of the Scientific and Technical Subcommittee, the topic for each season being selected by the Subcommittee at its previous session. The symposium was held on 21 and 22 February 1994, following the completion of the debate in the afternoon meetings of the Subcommittee.

3. In addition to the special presentations organized by COSPAR and IAF at the request of the Subcommittee, Member States organized a number of scientific and technical presentations, which were made by specialists in space science and applications, relating to various items on the agenda of the Subcommittee. Several international and national organizations also made special presentations on their scientific and technical activities.

4. In order to make more widely available the information on recent developments in space science, technology and applications presented during the symposium and the other presentations, the Secretariat has prepared a summary of that information, which is presented below.

5. The annex contains a more detailed description of the scientific and technical presentations made before the Scientific and Technical Subcommittee at its thirty-first session. Because of the technical character of the material, the annex is in English only. A list of the presentations and the speakers is contained in the appendix to the annex.

---

*Reissued for technical reasons.

SUMMARY OF PRESENTATIONS

6. After 35 years of space research, observation of the Earth by satellites is widely used in applications for disaster warning and prevention. Many different types of natural disasters or other catastrophic events frequently occur as a result of natural phenomena or human activities. These events may require short-term observations, as is the case for observing floods, forest fires, typhoons and earthquakes, or long-term monitoring, as is the case for desertification, deforestation, global warming and sea-level rise.

7. Observation of the Earth from satellites, with their ability to provide continuous monitoring and global, repetitive coverage, offers a number of advantages compared with other techniques. Digital data sets generated via satellite observations also facilitate the observation of rural and remote areas with difficult terrain and provide consistent data sets, which are important for thorough analyses.

8. The introduction of new technologies is sustaining and improving the effectiveness of satellite systems, but there is still no operational satellite system dedicated specifically to disaster monitoring. The European Space Agency (ESA), together with China, India, Japan and the United States of America, is playing a major role in deploying Earth observation satellites to be used for disaster warning and environmental monitoring.

9. ESA systems dedicated to disaster warning and environmental monitoring include the geostationary meteorological satellites of the Meteosat series and the polar-orbiting European Remote Sensing satellite (ERS) series. The utility of ERS-1 data for monitoring disasters or catastrophic events has already been demonstrated on various occasions and will be increased in fields such as atmospheric chemistry and the monitoring of land surface processes with the launch of ERS-2. The SPOT series of satellites, operated by a private company, provides high resolution optical images of the Earth's surface and the joint French/United States Topex/Poseidon satellite systems allow continuous monitoring of ocean topography.

10. Because of recent technological developments and ongoing research, many geophysicists now envisage the day when they will be able to predict natural disasters with some degree of accuracy. An encouraging indication of such progress is the proliferation of observations of signals and events that are associated with earthquakes and volcanic eruptions.

11. Space technology plays an important role in seismic risk mapping, which, particularly in intra-continental areas, requires mapping of all known faults, as earthquakes always occur on pre-existing faults. Since their respective launches, the SPOT and Landsat remote-sensing satellites have proved to be remarkably well equipped with fault-mapping tools. In some circumstances high-resolution space imaging can even be used to measure the cumulative displacement of the more active faults and can thus deduce displacement rates.

12. New techniques using synthetic aperture radar data are undergoing development and the images produced by ERS-1 satellites are ideal for predicting volcanic eruptions. The techniques make it possible not only to measure movements of the ground, but also to identify exactly the topography of the volcanic formations and the direction and ruggedness of the slopes. Those are crucial factors in anticipating the location and extent of lava flows.

13. In a few specific active zones, such as California, United States, these deformations are regularly measured within distances ranging from one kilometre to several hundred kilometres, in order to distinguish local influences associated with the seismic cycle. It is only by using spatial techniques that these measurements can be made over such a range of distances. For the longest-range measurements, satellite laser telemetry and interferometry techniques are used. At the local level, the preferred method is the application of Global Positioning System (GPS) satellites, which are now accurate to within a centimetre and can produce a detailed description of a deformation in the vicinity of a fault.

14. In the past decade the National Oceanic and Atmospheric Administration (NOAA) of the United States has established a temperature and moisture sounding capability in its new polar and geostationary satellite programmes. Data from these systems supplement the visible and infrared imagery available from other satellite systems. Applications of these technologies include temperature and moisture analyses for weather prediction, analysis of weather stability, estimation of tropical cyclone intensity and position, and global analysis of clouds.

15. Having accurate wind measurements is a prerequisite for predicting hurricanes. In a recent study of the past six hurricane seasons in the United States, NOAA satellites derived wind analyses, which produced a reduction of 10 per cent in the mean forecast error in hurricane track prediction and contributed significantly to early monitoring of such catastrophic events. Microwave observations from the current NOAA polar-orbiting satellites are also used to locate tropical cyclones and to estimate their surface intensity. By penetrating the cloud cover associated with tropical cyclones, it is possible to capture the characteristic upper-level warm temperature anomaly. This information is also valuable for predicting storms and the meteorological community is increasingly using it to supplement reconnaissance flight and other conventional data.

16. Desertification is defined as land degradation in arid, semi-arid and dry subhumid areas. It is caused by adverse human activities and climatic changes. The processes involved include wind and water erosion, salinization, waterlogging and chemical pollution. According to a desertification assessment made in 1991, 25 per cent of the Earth's surface is affected by desertification.

17. In China, where desertification is a serious problem and is the focus of a concerted containment effort, a map of erosion types and erosion intensity has been compiled by using the Landsat Thematic Mapper, multi spectral scanners and tunable laser spectrometers to make false colour composite satellite images and colour infrared aerial photos. In addition, another map was developed by combining geographical analysis with remote-sensing techniques, interpretation and land survey, which made it possible to evaluate erosion intensity. The use of such maps, created with the help of space technology, can lead to a better understanding of short- and long-term processes of erosion and desertification and can contribute to enhanced measures against these problems.

18. The experience in India has shown that the combination of telecommunications and meteorological satellites can be of great importance in predicting catastrophic events. While the capabilities of communication satellites in disaster warning, data transfer, and relief operations have been furthered by the advent of very small aperture terminals and ultra small aperture terminals, meteorological satellites are providing vital information on such variables as clouds, temperature, humidity and wind characteristics. These derived imageries are particularly useful in identifying cloud systems over the ocean, for tracking, assessing the intensity of and predicting storm surges and cyclones. One of their most notable uses occurred before a cyclone hit the coast of Andhra Pradesh in India in 1990. Over 170,000 people could be evacuated on time; thus, thousands of lives in that area were saved.

19. In Bangladesh, a nationwide flood forecasting and warning service has been developed by integrating satellite-derived cloud pattern data and field data. Significant achievements have also been made by China in satellite-based precipitation forecasting and flood management. In Nepal, NOAA images are used for flood warning in the entire region. The successful launching of the second generation of satellites of the Indian National Satellite System (INSAT) has greatly improved space technology applications in the fields of weather monitoring and disaster warning throughout the region.

20. A remote sensing-based National Agricultural Drought Assessment and Monitoring System for country-wide monitoring in India has been developed and is being used for operational monitoring. In the first phase, the System integrates rainfall and aridity anomalies with other data sets in order to provide realistic

assessment of droughts. Drought bulletins for drought-prone districts of the country are issued to relevant user agencies at all levels so they may take action if necessary. Based on user feedback, the second phase of the National Agricultural Drought Assessment and Monitoring System was launched in 1992. This phase includes detailed monthly drought assessment in terms of spatial variability and impact on crop and fodder production.

21. In 1975, as part of the follow-up to the World Food Conference, held at Rome from 5 to 16 November 1974, the Food and Agriculture Organization of the United Nations (FAO) established the Global Information and Early Warning System on Food and Agriculture. The primary purpose of the System is to monitor food supplies and demand conditions on a global scale, to identify countries or regions where food shortages are imminent and to assess possible emergency food requirements.

22. Since 1976, FAO has actively been developing and testing the use of data from environmental and Earth resource satellites for improving the databases of the Global Information and Early Warning System on Food and Agriculture and the Desert Locust Plague Prevention Programme at the international, regional and national levels. Starting in 1977, Meteosat imagery has been analysed visually for the monitoring of rainfall over Africa.

23. In 1985, a project was initiated to develop and implement a highly automated system for the acquisition, production and distribution of satellite data. The system, Africa Real Time Environmental Monitoring using Imaging Satellites (ARTEMIS), became operational in August 1988 and is still in service. ARTEMIS relies on two data sources: the NOAA series of satellites and Meteosat. The operational production at present covers Africa and the Near East and archived data go back to 1981. The data are continuously updated and are becoming more and more valuable, not only for early warning purposes, but also for more general environmental studies.

24. All the data produced by ARTEMIS are disseminated directly to a large number of users, both at FAO headquarters and in Africa. The users at FAO headquarters include the Global Information and Early Warning System on Food and Agriculture and the Desert Locust Plague Prevention Programme. The users within Africa, which include all national and regional early warning systems, depend mainly on pouch or courier services for data delivery, which can cause delays. Transmission of the data to certain locations in Africa, however, is now taking place via electronic mail facilities and the Direct Information Access Network for Africa (DIANA) system.

25. DIANA was developed by ESA in collaboration with FAO and currently is comprised of an uplink station in Italy and three microcomputer-based receiving stations, in Ghana, Kenya and Zimbabwe. Using these electronic communication channels, African users of ARTEMIS information are able to receive digital data without any delay.

26. In the future, ARTEMIS will increasingly be focusing on the provision of expertise and coordination in the fields of training, calibration and further development of application modules and low-cost systems, in addition to providing, by continuing the operational production of its routine maps, a backup to local production facilities. Furthermore, the development of regional programmes for environmental monitoring using remote-sensing satellites, thereby putting the early warning application in a wider context of environmental management, will be of great importance.

27. As a result of the increasing global population and population densities, the impact of natural disasters on humanity is becoming more and more severe. Although present space-based, air-based, and ground-based technologies make it possible to mitigate the effect of disasters, no worldwide disaster monitoring system has to date been put in place. Consequently, students of the International Space University have developed in a design study the Global Emergency Observation and Warning (GEOWARN) system, which could serve as

a worldwide institution for filling the current gaps of development in fields such as Earth observation, data processing, information dissemination, and telecommunication support for disaster warning and relief. The system, which would be open to all countries for humanitarian purposes, may be implemented over the next decade. The provision of detailed disaster information, the facilitation of emergency communications and the provision of interface personnel would be the main targets of the system. To that end, the GEOWARN system would strongly interact and cooperate with existing organizations such as FAO and the World Meteorological Organization (WMO).

28. Cooperation between new end-users and more traditional users is essential if the contribution that space can make is to be maximized. Space techniques can not only provide increasingly accurate and sophisticated measurements, but can also interrogate remotely situated sensors on the ground and transmit warnings and other large packets of information to multiple addresses. The real difficulties arise with the integration of different national and international ground infrastructures. The detection of an earthquake or the prediction of the track of a hurricane may be feasible, but it serves little practical purpose if the people affected are not warned immediately and either evacuated or given protection. The real application and benefits of these new techniques are dependent on integrating them into effective action on the ground.

29. On the question of the space environment, studies indicate that the evolution of the debris population is currently beyond human control. Only 22 per cent of all payloads currently in orbit are operational. Those functioning payloads represent only 5 per cent of the more than 7,000 objects tracked by United States military authorities. Redundant launch-vehicle upper stages represent an additional 16 per cent of the population, mission-related objects contribute a further 12 per cent, and fragments from breakups make up the remaining 45 per cent. Therefore, the behaviour of 95 per cent of the objects that can be tracked and all of the smaller size debris population cannot be controlled.

30. Research on space debris conducted in Germany is carried out either on a national basis or is funded under contracts with the ESA European Space Research and Technology Centre and the European Space Operations Centre (ESOC). The nationally funded research activities are largely concentrated in the Institute for Space Flight Technology and Nuclear Reactor Technology of the Technical University of Braunschweig and the Research Establishment for Applied Science (FGAN) under research contracts awarded by the German Space Agency (DARA) and ESA. Most of the work has been successfully performed in close cooperation with researchers from the National Aeronautics and Space Administration (NASA) of the United States.

31. Assessing the present and future risk to all space objects requires the use of models. The ESA meteoric and space debris terrestrial reference model has been developed by the Institute for Space Flight Technology and Nuclear Reactor Technology under an ESOC contract. The scope of the model covers human-made and natural objects larger than 0.1 mm in altitudes below 2,000 km. Analytical breakup models are used for the individual generation of the untracked debris population for the known on-orbit fragmentations (116 as of July 1993). The observable part of the debris population is monitored via ground-based radar measurements. For each generated population member, information is retained on its origin, mass, size and orbit. Flux information is resolved with respect to the source of impact, its mass, the impact velocity, the impact azimuth angle, the impact elevation angle and the position of the impact occurrence along the orbit of the target.

32. India has also developed theoretical models of debris generation caused by the disintegration of objects or by collision between objects. The models are designed to provide a better understanding of the untracked debris environment and predicting collision probability for operational spacecraft.

33. A joint research effort is being conducted by NASA and FGAN to characterize and compare debris shape, size, intrinsic motion, mass, and orbital lifetime of different types of breakups, for example from collisions and from explosions. At present, radar data on 30 debris objects (larger than 50 cm) are being

analysed. A statistical analysis of measured radar cross-section and a comparison with NASA results derived from effective areas of infrared, optical and radar measurements have also been started.

34. ESA has been actively addressing the space debris issue for several years. Its early concerns were the uncontrolled re-entry of spacecraft (e.g. the nuclear-powered Cosmos 954 and Skylab space station), collision risk in the geostationary orbit and ensuring the safety of manned spaceflight. The Council of ESA in 1989 defined the objectives of the Agency in the field of space debris and approved a plan of activities, which included as a main element a space debris programme. In 1990, the ESA space debris advisory group, composed of experts from ESA member States, was created to advise the Agency in all matters related to space debris. The purpose of the ESA space debris research programme is to reach a better understanding of critical issues and to carry out preparations for future programmes.

35. Europe has no system for space surveillance, that is, the systematic monitoring of all space objects. Some facilities exist, however, for the tracking of selected objects. They include the FGAN radar facility at Wachtberg, Germany. With a powerful 34-metre parabolic antenna, the radar, which operates in L-band and Ku-band, providing narrow-band as well as high-resolution radar data, space objects can be tracked over large areas of Europe. Research on the physical characteristics (radar cross-section, shape, mass, altitude) of space objects is carried out. Upon re-entry of risk objects, radar and optical stations in France also provide data for re-entry predictions. A survey on the use of ground- or space-based optical and infrared sensors for the detection and tracking of space debris has been carried out in the United Kingdom of Great Britain and Northern Ireland. Efforts are also being made to improve European ground-based observation capabilities with radar and optical sensors. Plans have been made to install a 1-metre Zeiss telescope on the Canary Islands of Spain as an optical ground site for a Silex experiment within the ARTEMIS project. After appropriate modifications and upgrades, the telescope can also be used for space debris observations, particularly for objects in geostationary and geostationary transfer orbits.

36. Research in the United Kingdom has shown that a quantitative assessment of detrimental impact will make it possible for environmental hazards of space debris to be characterized and for "acceptable" levels of degradation to be identified. The insurance industry will be keen to indirectly protect the future missions that they will underwrite by protecting the environment in which those assets will operate. Thus, a mission that would increase the hazard of collisions in orbit could be subject to penalty premiums, related to the detrimental impact of the mission. That would provide financial encouragement to operators to adopt appropriate debris mitigation practices in design and operations, or at least provide them with a cost trade-off between the two. The proposed quantitative approach therefore has two aims. The first is to encourage the adoption of debris mitigation principles in mission design by illustrating the cost benefits associated with such measures. The second is to maintain unlimited access to orbit for all responsible users who wish to continue to exploit the commercial, strategic and scientific potential of near-Earth space.

37. The United Kingdom has proposed a risk-based approach to the problem of possible collisions between space debris and satellites with nuclear power sources. Before an additional item of debris is created, it then becomes appropriate to evaluate the risk it poses over its lifetime to the whole population of orbiting items during that time and to compare the result with the cost of alternatives. Similarly, the risk from parking a satellite with a nuclear power source on board in a high orbit can be, in principle, evaluated taking account of existing debris. While this approach is technically demanding, it seems conceptually straightforward.

38. As space debris is a global problem that only can be solved by a joint effort, discussions and cooperation among space agencies and related organizations are of paramount importance. Regular coordination meetings have been held between ESA and NASA since 1987. In 1993, the Inter-Agency Space Debris Coordination Committee was created. Its members are ESA, entities from Japan, NASA and the Russian Space Agency. The primary purpose of the Committee is to exchange information on space debris research, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities

and to identify debris mitigation options. In particular, there is a recognized need to develop a common database of the space debris environment that will be supported by the surveillance networks and observation facilities of all the participants.

39. To mitigate the problem of space debris, space agencies have adopted some voluntary measures. For example, the National Centre for Space Studies (CNES) of France, together with Arianespace, instituted a policy of residual fuel venting from the upper stage of the Ariane launcher in case of launches into low altitude circular orbits (SPOT 2, ERS-1 and Topex/Poseidon) to prevent explosions. Since Ariane flight V59, fuel venting of the third stage has also been conducted as a routine procedure regardless of the type of the target orbit.

40. United States policy requires that space activities be carried out so as to minimize orbital debris. This policy requires each programme to conduct a formal assessment of its potential to generate orbital debris. A handbook to support implementation of the policy is being prepared by NASA to reduce the time and costs for performing such assessments and to assure that consistent standards and criteria are applied to all projects. This work is being sponsored by the office of safety and mission quality at NASA headquarters.

41. The problem of space debris is also being investigated by international organizations, such as IAF and the International Academy of Astronautics (IAA). IAA initiated a study to be performed by experts from its committee on safety, rescue and quality. The objectives are to evaluate the need for action and to indicate ways to reduce the hazards. The document containing the study was approved in October 1993 as an official IAA position paper.

42. India has its own satellite remote-sensing capability with complete space and ground infrastructure. Currently, two Indian remote-sensing satellites (IRS-1A and IRS-1B), equipped with linear imaging self-scanning sensors, provide data on the Indian subcontinent on a regular basis. The designed spectral resolution allows the identification of land cover vegetation with subtle spectral differences and enhanced mapping capabilities on large scales (i.e. 1:50,000). The new series of Indian remote-sensing satellites (IRS-1C/D) will form the second generation of the Indian remote-sensing system and will have improved features such as higher resolution, sensing capabilities in the middle infrared band, stereo viewing, repeated coverage of a particular area and on-board data processing.

43. India has used a variety of data from the NOAA Advanced Very High Resolution Radiometer (AVHRR) receiving station to conduct National Agricultural Drought Assessment and Monitoring System studies. The studies indicate a correlation of up to four weeks with rainfall and aridity anomaly. The forest cover maps generated by visual interpretation of Landsat and NOAA data show close similarity of closed forest, open/degraded forest and non-forest areas. A technique to evaluate potential vegetation cover using a multidate maximum vegetation index generated by the AVHRR receiving station of NOAA has also been developed in India. Such maps can be of immense value to studying vegetation, its phenology, biomass and productivity. The data could also be used in global climatic models for albedo, productivity as a function of carbon sink etc.

44. The Hubble Space Telescope is a collaborative project involving NASA and ESA. The telescope initially had a complement of five scientific instruments: two cameras, two spectrographs and one photometer. Light is collected by a mirror 2.4 metres in diameter. Within several weeks after launch, however, it became obvious that the mirror was polished to the wrong geometric shape, which resulted in images showing spherical aberration, that is, much less than the expected amount of energy was collected in the central peak of the images.

45. The Hubble Space Telescope was designed to be refurbished in orbit, as it was unlikely that all the components of the highly sophisticated space observatory would remain operational throughout the planned

15-year lifetime of the spacecraft. Thus, several of the malfunctions that occurred between 1990 and 1993 (most of which were temporarily corrected through the use of redundant components), had actually been anticipated. However, the main mirror could obviously not be exchanged in orbit. The solar panels, which caused serious operational problems because of thermally induced jitter, could be replaced in orbit, but replacement panels had to be manufactured. It was also fortunate that even before the launch of the Hubble Space Telescope, preparations had been made to replace the main camera on the telescope.

46. The astronauts that took part in the first Hubble Space Telescope servicing mission replaced failed gyroscopes and drive electronics, changed electrical fuses, replaced the solar arrays, installed a new wide field/planetary camera, installed new magnetometers, installed the corrective optics space telescope axial replacement, upgraded the on-board computer, installed new solar array drive electronics and installed a repair kit on the Goddard high-resolution spectrograph. The ambitious mission was executed with admirable success, after which the Hubble Space Telescope was boosted into a higher orbit.

47. It took several weeks for the Hubble Space Telescope to make the transition from operations prior to the instalment of the corrective optics space telescope axial replacement and those following its instalment. It was a carefully orchestrated undertaking designed to optimize the performance of all instruments. It was during that process that it became obvious that the servicing mission had been a tremendous success. Astronomers now have an excellent tool that is capable of answering many of the questions that modern astronomy poses.

48. Astronomers have been among the many beneficiaries of the dramatic scientific and technological progress that has been achieved worldwide since the 1950s, primarily through the development of more sensitive detectors, novel telescopes and the opportunity to not only observe from space, but also to fly by the other planets of the solar system. While bestowing powerful gifts upon the astronomical community, the technological age has also brought unprecedented levels of atmospheric noise to which radio astronomy is particularly vulnerable.

49. Despite the allocation of 2 per cent of all bandwidths for radioastronomy uses and the internationally binding nature of the relevant agreements of the International Telecommunication Union (ITU), there are daily violations of those reserved bands. Some violations arise from inadequate standards of electronic engineering that permit leakage or drift of transmitted power into the reserved band, or through the generation of harmonic frequencies that fall into a reserved band. Satellites of the Global Navigation Satellite System (GLONASS), which used spread frequency transmissions, made observation of the important astrophysical maser line at 1612 megahertz (MHz) almost impossible because they utilized that frequency as their central transmitting frequency. Fortunately, this unforeseen problem resulting from a shared band is now in the course of being resolved in favour of astronomers thanks to the good will of the GLONASS authorities. Astronomers will be looking forward to 1999, when the last unmodified GLONASS satellite will be phased out.

50. Space astronomy is also threatened, like every other activity in space, by the growing threat of space debris. The number of debris trails on deep sky astronomical plates has reached the point where one in three plates now carries one or more debris trails. Some plates are completely degraded for any scientific purpose by the sheer number of debris trails. A piece of debris crossing the field of view during photometric observations ruins the data and, if the trail is bright enough, may cause irreparable damage to sensitive detectors.

51. In recent years there have been a number of suggestions for the launch of large solar reflectors to mark particular events, for example the centenary of the Eiffel tower or the 1996 Olympic Games. To be seen on Earth, most of these proposals require the perceived brightness of the reflector to be that of the full Moon. Clearly, current proposals may not represent a significant threat to astronomy, but inevitable development

could lead to the abandonment of any ground-based astronomy because even small solar reflectors inadvertently reflecting a beam across an unsuspecting observatory could wreak havoc on sensitive instruments.

52. The astronomical community is using all the means at its disposal to inform responsible institutions about these threats posed to a science that has existed for millennia. Fortunately, there is support for astronomical science; for example, new outdoor lighting designs are available that can minimize upward light escape and the GLONASS transmission scheme is in the process of being redesigned. ITU still reserves frequency bands for radio astronomy; and the organizers of the 1996 Olympic Games at Atlanta, Georgia, in the United States have turned down a proposal to use a solar reflector as a means of advertising. In the absence of firm international agreements, however, too much depends on local bilateral agreements and on the efforts of a few dedicated people.

53. The first German Spacelab mission (D-1) was successfully completed in 1985. The second German Spacelab mission (D-2) was launched on 26 April 1993 on the space shuttle Columbia. On 6 May 1993, after 10 days in orbit at about 300 km altitude, 160 revolutions around the Earth and 6.7 million flight kilometres, the D-2 mission successfully ended. Sixty-two of the 89 scientific experiments carried out on the mission had been developed in Germany; of the remaining 27 experiments, France had developed 7, Denmark and Japan had each developed 4, Italy had developed 3, Belgium, the Netherlands and the United States had each developed 2 and Spain, Sweden and Switzerland had each developed 1. The D-2 mission was a truly international mission covering all scientific topics, including materials science (37 experiments), biology (18), human physiology (24), technology (2), Earth observation (2), astronomy (1), amateur radio (1) and even experimental subsatellites (4).

54. Brazilian space activities, coordinated by the National Institute for Space Research (INPE) of Brazil, will significantly expand in the near future. On 9 February 1993, an environmental data collection satellite, Satellite de Coleta de Dados (SCD-1) was successfully launched by a Pegasus vehicle into a low-Earth orbit with an inclination of 25° in order to provide adequate coverage of Brazil and particularly the Amazon region. A second satellite (SCD-2) will be ready to be launched into a similar orbit by late 1994.

55. Based on the experience of Satellite de Coleta de Dados, a more complex remote-sensing satellite equipped with a small camera is being developed by INPE. It should be able to transmit 200-metre resolution images in two visible spectral bands. It should be launched in 1996 with an indigenous launcher from Alcantara (in the Brazilian State of Maranhão) into sun-synchronous polar orbit at 640 km altitude. An identical satellite will be ready for a Brazilian launch in the period 1996-1997. China-Brazil Earth Resources Satellite (CBERS-1), the first remote-sensing satellite developed through a cooperative Brazilian/Chinese programme, is scheduled for launch by a Chinese Long March rocket in the period 1995-1996.

56. Between 1978 and 1991, small scientific satellites weighing about 50 kg were developed for the Magnetosphere-Ionosphere (MAGION) research programme in the former Czechoslovakia. Two more sophisticated MAGION-type subsatellites have been designed for the INTERBALL mission, which will study physical mechanisms of solar wind energy accumulation in the magnetosphere and dissipation of the energy in the auroral regions during magnetic substorms.

57. The INTERBALL mission consists of two pairs of spacecraft, situated in different orbits: one pair, the Auroral Probe, with an apogee of about 20,000 km; the other one, the Tail Probe, with an apogee of 200,000 km. Both orbits should have perigee heights of about 500 km and inclinations of 65°. Each pair of satellites consists of the main spacecraft of the Prognoz series, accompanied by a subsatellite of the MAGION type. The scientific objectives for the subsatellites are to separate time and space variations and to study spatial correlations and fine structures in the ionosphere and magnetosphere. Separation of the subsatellites will be controlled by small thrusters. The INTERBALL subsatellite payload and subsystems

have been developed and manufactured through an international cooperative effort involving Austria, Czech Republic, France, Germany, Poland, Romania, Russian Federation and Slovakia.

58. To develop a good model of satellite motion in the upper atmosphere, it is necessary to first have precise experimental data about atmospheric parameters and their spatial and temporal changes. An instrument that can measure all disturbing forces of non-gravitational origin (including atmospheric drag and lift) acting on a satellite is called an accelerometer, or a microaccelerometer if it is extremely sensitive. At the Astronomical Institute of the Czech Academy of Sciences, an accelerometer with a cubic proof-mass is now under development. The device, which is called MACEK, was tested in orbit in June 1992 on board the recoverable Resource F satellite.

59. The ultimate goal is to place the MACEK accelerometer on a dedicated satellite where it will be possible to get precise data on the atmospheric density distribution and variation. An opportunity to reach this goal is being presented by the Central European Satellite for Advanced Research (CESAR) project, undertaken in cooperation with Austria, Czech Republic, Hungary, Italy and Poland. The project is in the final stage of phase A, which involves agreeing on details of instrumentation, telemetric systems and orbit selection. The launching of the satellite to study the physical properties of the near-Earth environment is scheduled for 1997.

Note

1/ Official Records of the General Assembly, Forty-eighth Session, Supplement No. 20 (A/48/20), para. 80.

Annex

SCIENTIFIC AND TECHNICAL PRESENTATIONS TO THE SCIENTIFIC AND TECHNICAL SUBCOMMITTEE AT ITS THIRTY-FIRST SESSION*

CONTENTS

	Paragraphs	Page
I. SYMPOSIUM ON SPACE APPLICATIONS FOR DISASTER PREVENTION, WARNING, MITIGATION AND RELIEF	1-68	12
A. Space Applications for Disaster Prevention, Warning, Mitigation and Relief – The European Approach	1-7	12
B. The Use of Space Technology for Understanding and Predicting Earthquakes and Volcanic Eruptions	8-25	13
C. Remote Sensing of Severe Weather Events	26-31	15
D. Desertification and its Management in China	32-35	16
E. Floods and Droughts	36-48	16
F. Overview of FAO Remote Sensing Activities	49-56	18
G. GEOWARN – Global Emergency Observation and Warning	57-62	19
H. Synthesis	63-68	20
II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS	69-146	21
A. Space Debris Observation and Modelling	69-82	21
B. Space Debris Mitigation Techniques	83-97	23
C. Space Debris and NPS Safety	98-102	27
D. Remote Sensing Applications for Sustaining Biodiversity	103-117	27
E. Hubble Space Telescope Repair and First Scientific Results	118-123	31
F. Adverse Environmental Impacts on Astronomy	124-131	32
G. International Cooperation in Space Research	132-146	33
Appendix. List of scientific and technical preseatations		37

*This has not been formally edited.

I. SYMPOSIUM ON SPACE APPLICATIONS FOR DISASTER PREVENTION, WARNING, MITIGATION AND RELIEF

A. Space Applications for Disaster Prevention, Warning, Mitigation and Relief - The European Approach

1. After 35 years of space research, satellite Earth observation is widely used in applications for disaster prevention and warning. A large variety of disaster or catastrophic events occur frequently around the globe due to natural phenomena or man made activities. The observation of these events requires a wide scope of spatial and temporal scales. Short-term observations are used to monitor events such as floods, forest fires, typhoons, and earthquakes while long-term observations are required for the monitoring of phenomena such as desertification, deforestation, global warming and sea level rise.

2. Observation from space, with its continuous monitoring capability and global, repetitive coverage, offers a number of advantages compared to other techniques. Digital data sets also facilitate the observation of rural and remote areas over difficult terrain and provide consistent data sets, which are important for thorough analyses.

3. Very demanding observation requirements, particularly in terms of repetivity and spatial resolution, are required of Earth observations systems due to the wide variety of possible disasters and their random occurrence and the fact that they occur more often in certain seasonal periods and geographical zones. It is also of great importance for these systems to have all-weather observation capability.

4. The introduction of new technologies is sustaining and improving the effectiveness of such systems, but there is still no operational satellite system that is specifically dedicated to disaster monitoring. In the context of the establishment of a worldwide system for this purpose, Europe, through the European Space Agency (ESA), along with China, India, Japan and the United States of America, is playing a major role in deploying Earth observation satellites to be used for disaster warning and environmental monitoring.

5. ESA systems dedicated to these functions include the geostationary meteorological satellites of the Meteosat series and the polar-orbiting ERS series. The utility of ERS-1 data for monitoring disasters or catastrophic events has already been demonstrated on various occasions and will be increased in fields such as atmospheric chemistry and monitoring of land surface processes with the launch of ERS-2. The SPOT series of satellites, operated by a private company, provides high resolution optical images of the Earth's surface and the joint France-United States Topex-POSEIDON satellite systems allows continuous monitoring of ocean topography.

6. The development of more advanced sensors that will provide higher ground resolution and a further spectrum for monitoring atmospheric chemistry processes, as well as several approved new programmes at the European and national levels, will further enhance international capabilities to monitor and mitigate catastrophic events.

7. To meet future challenges and needs, it must be noted that spaceborne instruments can provide useful, and in many cases, unique data for the observation of disasters and should be supplemented by other data often made available via models. Future plans indicate that digital data will be more widely and effectively used as model assimilation techniques advance.

B. The Use of Space Technology for Understanding and Predicting Earthquakes and Volcanic Eruptions

8. The last 30 years have witnessed significant technological advances that have had an enormous impact on our daily activities and have considerably enhanced our living conditions. The sciences, particularly the Earth sciences, have also progressed in the same period and we can now observe and understand the Earth in its entirety. The tectonic plate model explains the origins of earthquakes and volcanic eruptions but even so, we are scarcely any better equipped to deal with the effects of telluric disasters than our ancestors were to cope with those devastating eruptions.

9. The construction of earthquake-proof buildings and installations does of course greatly reduce the potential risk of material damage and loss of life caused by earthquakes. However, these techniques are expensive and it hardly seems feasible to use them to rebuild all the cities located in high-risk areas around the world.

10. It could be said that seismic and volcanic risk is greater now than in the past, particularly due to the extremely high concentration of populations in urban areas. Due to population and building density, urban regions are more vulnerable to telluric disasters than are rural areas and the warning signs are harder to detect because of development on and below the ground and the higher level of noise generated by human activity.

11. Moreover, even though technological progress has reduced the risk of post-earthquake fires, such as those in San Francisco in 1906 and Tokyo in 1923, it has led to a proliferation of installations, such as dams, oil and gas storage facilities and, above all, nuclear power stations, whose destruction could have far more serious repercussions. Earthquakes are undoubtedly, among the most lethal, costly in economic terms, and threatening of the natural disasters to which our planet is prone.

12. For many geophysicists, the prediction of natural disasters can now be seriously envisaged, obviously on a short-term basis in the case of volcanic eruptions and, perhaps, also fairly rapidly in the case of earthquakes. An encouraging indication of such progress is the proliferation of observations of signals and events that are associated with earthquakes and volcanic eruptions. It must be noted that the knowledge gained about the deformation in the Earth's crust is one of the fastest developing areas and makes extensive use of space technology.

13. The acknowledged existence of some successful short-term predictions of earthquakes and volcanic eruptions, and the constant improvement in long-term prediction capabilities are also encouraging indications of current developments in these research fields. The most celebrated example is the prediction of the Haicheng (China) earthquake, which occurred on 5 February 1975. However, the tragic outcome of the Tangshan earthquake in 1977, which killed over 500,000 people in an area only a few hundred kilometres from Haicheng, shows how limited current prediction methods are.

14. The method used in Haicheng was based, like most short-term predictions, on an empirical analysis of a very large number of observations made systematically over nearly 10 years. Taken together, these observations revealed anomalies in the spatial distribution and current space missions have clearly shown the ability of satellites to make repeated observations over long periods of time on a scale that is difficult to achieve through ground observations.

15. Satellites are therefore essential for monitoring high-risk areas around the world. A satellite in polar orbit makes one complete orbit in about 100 minutes. It is thus possible to have global coverage of the Earth in a few days. The ERS-1 satellite is now able, with an appropriate data-gathering system, to photograph

the entire planet's surface with a resolution of a few metres in 35 days. Of course, the use of satellites means that some of the crucial parameters mentioned earlier can be observed from space.

16. As far as seismic risk mapping is concerned, there is a simple rule particularly in intra-continental areas: earthquakes always occur on a pre-existing fault. Risk mapping thus consists of mapping all faults. Since their launching, the SPOT and LANDSAT remote sensing satellites have proved to be remarkably well-equipped with fault-mapping tools. In some circumstances high-resolution space imaging can even be used to measure the cumulative displacement of the more active faults and thus to deduce displacement rates. Hence the current degree of resolution of the SPOT pictures permits precise measurement of changes in river beds and recent sediments.

17. In the case of volcanoes, the extent of this phenomenon and the places where it appears are straightforward criteria for assessing risk. In order to measure the volumes of lava emitted, and variations in the timing of these emissions during an eruption – two key parameters for determining volcano dynamics – remote sensing methods again represent a powerful tool.

18. New techniques using Synthetic Aperture Radar (SAR) data are undergoing active development and the images produced by ERS-1 satellite data are ideal for predicting volcanic eruptions. This technique enables one not only to measure movements of the ground, but also to identify exactly the topography of the volcanic formations and the direction and ruggedness of the slopes. These are crucial factors in anticipating the location and extent of lava flows.

19. In a few specific active zones, such as California, United States, these deformations are regularly measured within distances ranging from one kilometre to several hundred kilometres, in order to distinguish local influences associated with the seismic cycle. It is only by using spatial techniques that these measurements can be made over such a range of distances. For the longest-range measurements, the techniques used are satellite laser telemetry and interferometry. At the local level, the preferred method is the application of Global Positioning Systems (GPS) which are now accurate to within a centimetre and can produce a detailed description of the deformation in the vicinity of the fault.

20. Landslides represent another major geophysical risk. The instability of mountain slopes, resulting in landslides, is usually caused by the gradual erosion of mountains and massifs. The risk is increased by the weathering of rock and soils, especially as a result of water infiltration. But the biggest landslides are often of tectonic origin, and are caused by movement in active faults and are sometimes even set off by a nearby earthquake. Hence, they may be an aggravating factor in the destruction caused in an earthquake zone.

21. Here again, space geodesy, especially SAR interferometry, is an ideal technique for monitoring these phenomena. Presently a trial survey of a landslide in the Alps is being conducted using SAR images from ERS-1. In this survey, a range of ground movements varying along the landslide, from 0.2-1.0 cm per day has been noted.

22. Other kinds of sensors, installed or programmed on satellites, which can provide crucial information about the activity and potential risks of volcanic activity are also of interest for predicting catastrophic events. The first type consists of visible imaging systems such as SPOT and LANDSAT, which provide images of volcanoes and their features by combining channels. The others are mainly infrared and ultraviolet measuring systems for estimating the surface temperature of volcanic formations and the volumes of sulphur dioxide emitted by volcanoes. Geostationary satellites which take very low-resolution photographs, in both visible and infrared bands, are also a vital source of information for studying the risks caused by emissions of aerosols and gases from volcanoes.

23. Every year there are several dozen earthquakes in the world of a magnitude greater than 6.5 on the Richter scale. The understanding of this phenomenon is still far from complete, chiefly because of the small amount of data available. In fact, in most cases the only geophysical observations made are recordings of seismic signals taken at a distance of several thousand kilometres from the source.

24. Mechanisms for the rapid deployment of networks supported through local seismic monitoring stations in the affected zones have been established in a number of countries allowing them to study the characteristics and distribution of aftershocks which also represent a major source of information and are very often responsible for additional damage and casualties. But the deployment of these networks is often not undertaken until several days after the first tremor, and depends to a great extent on the meteorological and political conditions in the affected zone.

25. At the same time, it is already possible to build automatic, non-recoverable seismic monitoring stations which are easy to install. The data gathered can then be transferred via the EUMETSAT, INMARSAT and INTELSAT communications systems. In the very near future the number of such networks will increase as will the volume of data to be transmitted. Furthermore, the need to transmit in "real time" will also grow in line with improvements in the ability to predict seismic disturbances. In this context, satellites can play a key and vital role in monitoring, predicting and mitigating the consequences of natural disasters.

C. Remote Sensing of Severe Weather Events

26. In the past decade the United States National Oceanic and Atmospheric Administration (NOAA) has established a temperature and moisture sounding capability in its new polar and geostationary satellite programmes. These systems have supplemented the visible and infrared imagery previously available. Applications of these technologies include temperature and moisture analyses for weather prediction, analysis of weather stability, estimation of tropical cyclone intensity and position, and global analysis of clouds. The use of satellites also extends to NOAA's climate programme which allows the computation of models on the effect of aerosols and greenhouse gases and possible global warming trends.

27. In addition to imaging the Earth's atmosphere with visible reflected and thermal emitted radiances, the observations are used to calculate the atmospheric temperature for obtaining moisture profiles, surface temperatures and cloud parameters. Many of these applications are pertinent to operational short-range forecasting. The quality of the models developed indicates that there is cause for optimism in the operational application of satellite sounding products and it has been recognized that the applications of these data at present has not been exhaustive.

28. Wind measurements remain the most important factor for the prediction of hurricanes. In a recent study of the past six hurricanes seasons in the United States, these satellites derived wind analyses which produced a 10 per cent reduction in the mean forecast error in hurricane track prediction and contributed significantly to early monitoring of such catastrophic events.

29. Microwave observations from the current NOAA polar orbiting satellites have also been successfully used to locate tropical cyclones and to estimate their surface intensity. By penetrating the cloud cover associated with tropical cyclones, it is possible to capture the characteristic upper level warm temperature anomaly. This valuable information in the prediction of storms is increasingly being sought by the meteorological community to supplement reconnaissance flight and other conventional data.

30. The analyses of temperature and moisture for severe weather monitoring and prediction can also be conducted with the assistance of polar orbiting and geostationary satellites. Timeliness and the continuity

of data, as well as a proper understanding and interpretation of the data derived, are essential for the operational use of satellites in forecasting catastrophic events.

31. It is apparent that the existing database from NOAA's polar and geostationary satellites is an integral part of the ongoing investigation of the Earth and its atmosphere. While future observing developments will enhance the capability to probe the Earth system, the data from the current series of satellites are already proving to be a useful tool for the understanding of the global habitat and coming changes.

D. Desertification and its Management in China

32. Desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas. It is caused by adverse human activities and climatic changes. It causes degradation of grasslands and reduced soil fertility. The processes involved include wind and water erosion, salinization, waterlogging and chemical pollution.

33. Based on a desertification assessment made by the United Nations in 1991, 25 per cent of the Earth's surface is affected by desertification. Adverse effects of human activities are the main causes. Degradation of the land is caused by overgrazing, felling of forests, irrational agricultural uses and activities related to industry and mining. Therefore, desertification or land degradation is recognized as a global environmental issue and attracts attentions from all over the world. China, with it's vast territory, various physical environments and huge population, has had to master the problem of desertification for many centuries. Consequently, desertification and its proper management has been proceeding on a very large scale

34. A comprehensive management strategy and a series of engineering and biological measures has been implemented. Measures include slope modification, valley construction, soil-erosion protection, tree or shrub shelterbelts and other agro-measures, in order to increase surface roughness of farmlands so as to decrease sheet erosion. With regard to desertification and its management, the use of satellites and remote sensing data is not only feasible for detecting changes occurring in the environment but has far better results than other methods.

35. For example, a map of erosion types and erosion intensity has been compiled through the use of LANDSAT Thematic Mapper (TM) and Multi-Spectral Scanner (MSS), and Tunable Laser Spectrometer (TLS) false colour composite satellite images and colour infrared aerial photos. In addition, another map was developed by combining geographic analysis with remote sensing techniques, interpretation and land survey, which allowed the evaluation of erosion intensity. The use of such maps, created with the help of space technology, can lead to a better understanding of short- and long-term processes of erosion and lead to improving countermeasures against these problems.

E. Floods and Droughts

36. For as long as humanity has been present on the Earth, it has been vulnerable to extremes of climatic fluctuations. At present, there is enormous concern about the changes that are occurring on the surface of the Earth and in its atmosphere, primarily due to human intervention with nature. These changes are likely to alter the hydrologic cycles which have a profound impact on the occurrence of floods and droughts. Developing countries, which are less equipped to recover from these events, are also the least prepared and protected and, as a result, suffer the most devastation from them.

37. Over the last four decades, in Bangladesh alone, more than 250,000 people have died due to natural disasters, primarily floods. In India, nearly 25 per cent of the population lives in drought and flood prone areas.

38. Floods and droughts occur so frequently, and cause so much devastation that economic development, social stability, and environmental quality are adversely affected all over the world. Although these phenomena are inevitable, it is possible to reduce their impact through effective action plans and more efficient management of resources.

39. Space technology has already made substantial contributions to every aspect of flood and drought management, including preparedness, prevention and relief. While satellite communications have significant potential for real-time dissemination of information and early warning, Earth observation satellites enable the user to continuously monitor atmospheric and surface parameters attributed to these phenomena. The considerable knowledge gained in the operational use of space technology for management and mitigation of floods and droughts should in the near future provide viable technological solutions to these problems.

40. Though several countries, including some developing nations, are using space technology to address these problems in their respective regions, many developing countries do not yet have the necessary infrastructure and required level of trained manpower to absorb this type of technology for direct problem solving. It is equally important to bridge the "knowledge gap" between those who can use space technology and those who cannot, through meaningful and active international and regional cooperation schemes to ensure an effective management of floods and droughts at all levels.

41. The experience in India, for example, has shown that the combination of telecommunications and meteorological satellites can be of great importance in predicting catastrophic events. While the capabilities of communication satellites in disaster warning, data transfer and relief operations have been furthered with the advent of Very Small Aperture Terminals (VSATs) and Ultra Small Aperture Terminals (USATs), meteorological satellites are providing vital information on clouds, temperature, humidity, wind characteristics, etc. These derived imageries are particularly useful in identifying cloud systems over the ocean, for cyclone tracking, intensity assessment and prediction of storm surges. Outgoing long-wave radiation, along with precipitation data provide valuable input to numerical weather prediction models.

42. Besides providing input for quantitative estimation of precipitation, geostationary satellites have become increasingly helpful in the collection of data on rainfall and river stages in remote and uninhabited locations. The implementation of a local disaster warning system, consisting of a number of disaster warning receivers to provide timely warning in the coastal villages of India, has been another innovative application. One of the most notable uses occurred during the cyclone that hit the Andhra Pradesh coast in 1990, and which enabled the government to evacuate over 170,000 people, thus saving thousands of lives in this area.

43. In Bangladesh, a nationwide flood forecasting and warning service has been developed through the integration of satellite derived cloud pattern data and field data. Significant achievements have also been made in satellite-based precipitation forecasting and flood management by China. In Nepal, NOAA images are used for flood warning in the entire region. The successful launching and operation of the second generation of Indian INSAT satellites has greatly improved space technology applications in the fields of weather monitoring and disaster warning throughout the region.

44. Throughout the region, satellite-derived vegetation indices, which are sensitive to vegetation stress are now being continuously used to monitor drought conditions on a real-time basis. These indices help decision-makers to initiate strategies for recovery by changing crop patterns and various agricultural practices. The use of meteorological satellite data to assess the spatial and temporal inadequacies of rainfall at critical crop stages and subsequent assessment of crop status also provides an excellent drought monitoring mechanism.

45. A remote sensing-based National Agricultural Drought Assessment and Monitoring System (NADAMS) for countrywide monitoring in India has been developed and is being used for operational monitoring. In the first phase, the system integrates rainfall and aridity anomalies with other data sets in order to provide realistic assessment of droughts. Bi-weekly drought bulletins for drought prone districts of the country are issued to concerned user agencies at all levels so that they may take any necessary action. Based on user feedback, the second phase of NADAMS was launched in 1992. This phase includes detailed monthly drought assessment in terms of spatial variability and impact on crop/fodder production.

46. Although a number of satellites currently provide data covering a wide spectrum of the Earth's environment, it must be noted that no single satellite mission can provide the full range of measurements needed to meet the requirements for efficient flood and drought management. There is thus a need for using complementary and supplementary data from different satellites requiring data compatibility in terms of formats and calibration. Having the necessary uninterrupted data supply within short turn around time requirements is a major "bottle neck" which needs to be solved through proper international cooperation.

47. Because of the direct relevance of space technology for addressing problems related to floods and droughts, there is an urgent need for appropriate technology transfer, and the adaptation of this technology and its assimilation in the existing socio-cultural environment of developing countries. Agenda 21 (of the United Nations Conference on Environment and Development) advocated the transfer of technology including know-how, procedures, goods, services and equipment, as well as organizational and managerial procedures. The use of space technology for flood management in China, and the long-term drought proofing in India, are some useful examples which could be transferred to other nations that have similar problems.

48. Several developing countries are currently using space technology to address the issues related to flood and drought management in their regions. In view of this, the International Decade for Natural Disaster Reduction assumes paramount importance for mobilizing global efforts to improve the utilization of space technology for better management and mitigation of floods and droughts.

F. Overview of FAO Remote Sensing Activities

49. The world food crisis in the early 1970s proved to governments, international organizations and the general public that there was a real need for a continuous flow of up-to-date information on the outlook of the supply of man's basic foods. In 1975, as a follow-up to the 1974 World Food Conference, the Food and Agriculture Organization (FAO) of the United Nations established the Global Information and Early Warning System (GIEWS) on Food and Agriculture. The primary purpose of GIEWS is to monitor food supply and demand conditions on a global scale, identify countries or regions where food shortages are imminent and assess possible emergency food requirements. As such, GIEWS is the only comprehensive international source for information on current and prospective food supply/demand situations in all countries of the world.

50. Since 1976 FAO has actively been developing and testing the operational use of data from environmental and Earth resources satellites for improving the information bases of GIEWS and the Desert Locust Plague Prevention Programme at the international, regional and national levels. Starting in 1977, Meteosat imagery was analyzed visually for the monitoring of rainfall over Africa.

51. In 1985, a project was initiated to develop and implement a highly automated satellite data acquisition, production and distribution system. This system, the Africa Real Time Environmental Monitoring Information System (ARTEMIS), became operational in August 1988 and is still in service.

52. For the timely supply of information on growing conditions and vegetation development, the ARTEMIS system relies on two data sources: the NOAA series of satellites and Meteosat. The operational production

at present covers Africa and the Near East and archived data goes back to 1981. This archive is continuously updated and becomes more and more valuable, not only for early warning purposes, but also for more general environmental studies.

53. All the data produced by the system are disseminated directly to a large number of users, both at FAO Headquarters as well as in Africa. The Headquarters users include the GIEWS and the Desert Locust Plague Prevention Group. Users within Africa included virtually all national and regional early warning systems but depend mainly on pouch or courier services, which can cause undesirable delays. However, electronic transmission of the data to certain locations in Africa is now taking place via electronic mail facilities and the Direct Information Access Network for Africa (DIANA) system.

54. DIANA was developed by ESA in collaboration with FAO and currently is comprised of an up-link station in Italy and three microcomputer-based receiving stations in Ghana, Zimbabwe and Kenya. Using these electronic communication channels, when available, African users of ARTEMIS information are able to receive digital data without any delay.

55. Recent developments include the increased use of ARTEMIS data on standard microcomputers, the increased use of ARTEMIS data at the national and regional level in Africa and the increased (near) real-time access to Meteosat and NOAA derived products. Local reception and processing facilities and telecommunication developments such as DIANA and the increasing availability of electronic mail are also facilitating the use of ARTEMIS data.

56. In the future ARTEMIS will, in addition to providing information to Headquarters users, increasingly focus on the provision of expertise and coordination in the fields of training, calibration and further development of application modules and low-cost systems, as well as providing, through continuation of the operational production of its routine maps, a back-up to local production facilities. Furthermore the development of regional programmes for environmental monitoring using satellite remote sensing, thereby putting the early warning application in a wider context of environmental management, will be of great importance.

G. GEOWARN – Global Emergency Observation and Warning

57. Due to the increase in global population as well as in population densities, the impact of natural disasters on humanity is becoming more and more severe. Although current space-based, air-based, and ground-based technologies enable mankind to mitigate the effect of disasters, no worldwide disaster monitoring system has to yet been put in place.

58. Consequently, students of the International Space University developed in a design study the Global Emergency Observation and Warning (GEOWARN) system which could serve as a worldwide institution for filling the current gaps of development in fields such as Earth observation, data processing, information dissemination, and telecommunication support for disaster warning and relief. The system would be open to all nations for humanitarian purposes and may be implemented over the next decade. GEOWARN would primarily provide global disaster warning, notification and relief support services. Detailed disaster information, the facilitation of emergency communications and the provision of interface personnel would be the main target of the system. To this end, GEOWARN would strongly interact and cooperate with existing organizations such as FAO and WMO.

59. In order to arrive at effective and economically reasonable system requirements, the highest priority natural disasters such as floods, hurricanes, earthquakes, droughts, insect infestations and crop diseases were defined by the multinational group of students. To effectively monitor these types of disasters, it was proposed to establish a data gathering system that would consist of internal installations, including six Earth-

observing LEO satellites, 30 remote sensing aircraft, and data archives, and would incorporate external facilities such as the existing meteorological and seismological centres, databases and research institutions.

60. The GEOWARN system's brain would be located in five relatively autonomous centres, each providing GEOWARN services to a specific part of the world. In these centres the data would be collected, processed, interpreted, and archived. The GEOWARN system's interconnection as well as the connection to the outside world may be accomplished by a flexible communication net consisting of ordinary post and telegraph lines, INTERNET, fixed INTELSAT, and mobile INMARSAT links.

61. The primary users of the GEOWARN system would be the respective governments affected by disasters and the Secretariat of the United Nations. They would be notified immediately in times of impending disasters. Secondary users would have to be explicitly authorized by the primary users to request and receive warning relief information. This group may include local authorities, local emergency agencies, relief agencies, church organizations, and the media. Tertiary users may gain access to the GEOWARN database and archives for humanitarian research activities and would include universities and research institutes.

62. GEOWARN would be an international, non-profit, politically neutral, and non-discriminatory organization with governments as shareholders. The organization would consist of an Assembly of Representatives on a one-nation, one-vote basis, a Board of Directors with a voting power proportional to investment share, and a Directorate which would coordinate the centres. It is impossible to predict how many lives GEOWARN may save. However, it was expressed by the student body that if only 0.5 per cent of the economic damage caused by disasters yearly could be prevented, then the estimated average annual cost of the system, $470 million, would be justified.

H. Synthesis: Space Applications for Disaster Prevention, Warning, Mitigation and Relief

63. At any given time, tens of millions, even hundreds of millions of people are at risk from some form of natural disaster. The material cost of such disasters has been calculated to be tens of billions of dollars annually and not only people in developing countries are at risk. Therefore, in the field of disaster prevention, the active interest and help of all concerned entities is essential for limiting the human and economic costs of natural disasters.

64. There are existing plans for maintaining and greatly extending the capacity to make measurements from space, and new instruments which are more flexible and offer better results are continuously being developed. It is also encouraging that more attention is apparently being given to the ground segment of such systems which traditionally represented the poor relation in many space programmes. This will help to improve and facilitate the processing of the vast amounts of data which are generated from spaceborne systems.

65. Connected with the space element, scientists are working to get the most out of existing sensors and to determine what improvements can be made to future instruments. End-user scientists, geologists, geographers, meteorologists, soil scientists, irrigation and drainage engineers, and oceanographers, who wish to improve their understanding of natural disaster phenomena, are increasingly using space technology to enhance their capabilities to predict natural disasters.

66. Cooperation between new end-users and more traditional users is essential if the contribution which space can make is to be maximized. Space techniques can not only provide increasingly accurate and sophisticated measurements, but can interrogate remotely situated sensors on the ground and transmit warnings and other large packets of information to multiple addresses.

67. The real difficulties arise with the integration of different national and international ground infrastructures. The detection of an earthquake or the prediction of the track of a hurricane may be feasible but it serves little practical purpose if the people affected are not warned immediately and either evacuated or given protection. The real application and pay-off in these new techniques are dependent on integrating them into effective action on the ground.

68. The major aims of using space applications for disaster prevention, warning, mitigation and relief can be seen in a continuous education about what space techniques can do and cannot do, in the better exploitation of existing satellite data and their combination with non-space data into useable and timely information and management schemes. Finally methods, technologies, hardware and software used should meet end-user needs and fully incorporate their own capabilities.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

A. Space Debris Observation and Modelling

69. During 36 years of orbital operations, more than 23,000 individual trackable objects have been placed into orbit around the Earth. As of early 1994, more than 7,000 of these objects remained in orbit. In order for the United States Space Command to be able to track these objects, they must have dimensions greater than 10 cm in low Earth orbit (LEO) and 100 cm in geostationary orbit (GSO). In addition, there is estimated to be a population of smaller objects (1 cm < d < 10 cm) which exceeds the number of trackable objects by at least an order of magnitude, and which is capable of causing the catastrophic breakup of operational satellites. A further, even larger population of smaller debris objects (d < 1 cm), though less likely to cause a catastrophic breakup of a satellite, can cause a significant degradation in satellite system and subsystem performance. The collision hazard presented by the debris is due to the high energy of impact: encounter velocities can be of the order of 10-15 km/s in LEO.

70. At present, the evolution of the debris population is beyond human control. Only 22 per cent of all payloads currently in orbit are operational. These functioning payloads represent only 5 per cent of the more than 7,000 objects tracked on a regular basis by the United States Space Command. Redundant launch vehicle upper stages represent an additional 16 per cent of the population, mission-related objects contribute a further 12 per cent, and fragments from breakups make up the remaining 45 per cent. Therefore, the behaviour of 95 per cent of the trackable objects and all of the smaller size debris population, cannot be controlled.

71. German activities in the field of space debris cover a wide range and are supervised by the German Space Agency (DARA). German research activities can be grouped under the following headings:

- methods of debris detection;
- modelling of space debris;
- trend analysis;
- investigation of hypervelocity impact phenomena;
- test and numerical simulation;
- development of debris protection systems;
- debris prevention and removal.

72. German research activities are either conducted on a purely national basis or are funded under contracts with ESA's European Space Research and Technology Center (ESTEC) and the European Space Operations Center (ESOC). The nationally funded research activities are largely concentrated in the Institute for Space Flight Technology and Nuclear Reactor Technology of the Technical University of

Braunschweig (IfRR/TUBS) and the Research Establishment for Applied Science (FGAN) under research contracts awarded by DARA and ESA. Most of the work has been performed in close and successful cooperation with researchers from the United States National Aeronautics and Space Administration (NASA)

73. Assessing the present and future risk to all space objects requires the use of models. The ESA Meteoric And Space Debris Terrestrial Reference Model (MASTER) has been developed by IfRR under an ESOC contract. The scope of the model covers man-made and natural objects larger than 0.1 mm in altitudes below 2,000 km. Analytical break-up models are used for the individual generation of the untrackable debris population for the known on-orbit fragmentations (116 up to July 1993). The observable part of the population is considered through ground-based radar measurements. For each generated population member, information is retained on its origin, mass, size and orbit. Flux information is resolved with respect to the impactor source, its mass, the impact velocity, impact azimuth angle, impact elevation angle and the position of the impact occurrence along the target's orbit.

74. The analyses carried out on samples returned from the Long Duration Exposure Facility (LDEF) satellite underline the existence of a large number of small debris particles orbiting on highly elliptical orbits with low inclinations. In addition, the existence of small particles on sun-synchronous orbits (near-circular with high inclinations) must also be assumed to explain the observational data on LDEF's leading surface. From further analyses, which allow for the conversion of crater frequencies into particle fluxes, it can be assumed that present orbital debris models are underestimating the environment in the 0.1 mm size range by a factor of 2 to 3. Hence, the impact data to be gained by analysis of ESA's European Retrievable Carrier (EURECA) platform and the Hubble Space Telescope's solar array will be of major importance in view of this topic.

75. In order to more precisely assess the long-term effects of orbital mechanics for the purpose of space debris modelling, a special computer code (LOPEX) has been developed at IfRR/TUBS. This code allows for analyzing the behaviour of different types of orbits (from circular to highly elliptical in various altitude regimes) over periods up to several hundreds of years taking into account the relevant orbital perturbations with a sufficient degree of accuracy. Hence, it can be used to evaluate the effectiveness of storage concepts (e.g. graveyard orbits) for those kinds of orbits, which will not become subject to direct debris prevention measures due to technical and economical reasons. The interaction of debris on geostationary transfer orbit (GTO) and other highly elliptical orbits within the geostationary ring can also be analyzed.

76. The objective of a NASA/FGAN joint research investigation is to characterize and compare debris shape, size, intrinsic motion, mass, and orbital lifetime from different types of breakups, for example, from collisions and explosions. At present, radar data on 30 debris objects (size larger than 50 cm) are being analyzed. A statistical analysis of measured radar cross section (RCS) and a comparison with NASA results derived from effective areas of infrared, optical, and radar measurements has also been started.

77. ESA has been actively addressing the space debris issue for several years. Its early concerns were the uncontrolled re-entry of spacecraft (e.g. the nuclear powered Cosmos 954 and Skylab space station), collision risk in the geostationary orbit (GSO) and ensuring the safety of manned spaceflight. In 1985, a workshop was held at ESOC to discuss the problem of uncontrolled re-entry of risk objects. In 1986, the Director General of ESA established the Space Debris Working Group (SDWG) with a mandate to assess the various issues of space debris. Based on the findings and conclusions of the SDWG (published in ESA's Report on Space Debris, ESA-SP 1109), the Council of ESA in 1989 defined the Agency's objectives in the field of space debris and approved a plan of activities, which includes as a main element, a space debris programme. In 1990, the ESA Space Debris Advisory Group (SDAG), composed of experts from ESA member states, was created to advise the Agency in all matters related to space debris.

78. The purpose of ESA's Space Debris Research Programme is to reach a better understanding of critical issues and to prepare for future programmes. It covers three main areas:

- Knowledge of the terrestrial particulate environment;
- Assessment of the risk posed by space debris; and
- Protective and preventive measures.

79. Europe has no system for space surveillance, i.e. the systematic monitoring of all space objects. However, some facilities exist for the tracking of selected objects. They comprise 34-m parabolic antenna radar at FGAN in Wachtberg-Werthoven, Germany. With this powerful radar, which operates in L-band and Ku-band providing narrow-band as well as high resolution radar data, space objects can be tracked over large areas of Europe. Research on the physical characteristics (RCS, shape, mass, altitude) of space objects is carried out. Upon re-entry of risk objects, radar and optical stations in France also provide data for re-entry predictions. A survey on the use of ground- or space-based optical and infrared sensors for the detection and tracking of space debris has been carried out in the United Kingdom of Great Britain and Northern Ireland. Efforts are also being made to improve European ground-based observation capabilities with radar and optical sensors. A one-metre Zeiss telescope is planned to be installed on the Canary Islands as an optical ground site for the Silex experiment within the ARTEMIS project. After appropriate modifications and upgrades, the telescope can also be used for space debris observations, particularly for objects in GTO and GSO.

80. Under a contract with the Unit for Space Science at the University of Kent in Canterbury, England, ESA has established the DISCOS space debris database at ESOC in Darmstadt, Germany, for its own use and for that of member state institutions. It supplies information on the currently catalogued objects and is a basis for risk assessments and understanding of the evolution of the space debris environment. DISCOS contains as major elements the NASA "two-line orbital elements" which are regularly updated, the NASA Situation Report, the Royal Aircraft Establishment (RAE) Table of Earth Satellites and information on satellite fragmentation history.

81. Based on existing meteoroid and debris models, the particulate flux near a space vehicle can be modeled. ESA analyses show that the current population of debris does not represent an immediate and excessive danger. For example, during a five-year period, the chance of an ERS satellite colliding with a 1 cm or larger particle is 1 per cent to 2 per cent. However, the risk of collision with debris is steadily growing. Of most concern are the long-term prospects in low-Earth orbit (LEO) and in GSO, the two most heavily used and endangered regions in space.

82. Theoretical models of debris generation caused by the disintegration of objects or by collision between objects have also been conducted in other countries, for example in India. These studies are aimed at better understanding the untracked debris environment and predicting collision probability for operational spacecraft. In spite of different initial assumptions, their conclusions are in general agreement.

B. Space Debris Mitigation Techniques

83. An object is removed from orbit when either atmospheric drag reduces its orbital energy or it is actively de-orbited through a propulsive manoeuvre or retrieval. Atmospheric drag, however, is only effective at removing objects from orbit at altitudes below 600 km. Above this altitude the atmosphere is too rarefied to return objects to Earth within an acceptable time. It is unrealistic to propose, or expect, active retrieval of redundant objects currently in orbit. The objective must therefore be to prevent the debris environment from further deterioration through debris mitigation measures applied to future missions. If these measures are implemented, the onset of cascade fragmentation is prevented and thereby ensured access to near-Earth space continues. In considering ways to control debris deposition, one must guard against any limitation on

the use of Earth orbit by responsible operators, and seek only to restrict design and operational practices when they can be shown to have a significant detrimental effect on the orbital environment.

84. A technical framework must be established to assess the hazard that future debris will represent to the orbital environment. This may then form the basis of any initiatives to control the debris deposition into orbit. The assessment of detrimental environmental impact must be applied to all objects injected into orbit by the mission which become debris. This will include the payload and launch vehicle at the end of their operational lifetimes. Existing initiatives aimed at controlling the deposition of debris into Earth orbit have only been linked to qualitative statements which are not easily applied to regulatory measures. The quantitative assessment of the potential detrimental impact of a space mission is easier to apply to any initiative to control space debris, but even in its simplest form, this is a complex, multidimensional problem.

85. According to an expert from the United Kingdom, a quantitative assessment of detrimental impact will permit the environmental hazard to be characterized and "acceptable" levels of degradation to be identified. No measure of detrimental impact in this context, however, currently exists. Terrestrial pollution and permissible levels of degradation, are not assessed directly in terms of the deterioration in the environment, but indirectly in terms of the level of degradation that the ecological system can support without suffering harmful consequences. It is proposed that an assessment of the detrimental impact of a space mission can be measured in a similar fashion, in terms of the collision hazard it presents to the population of operational satellites residing in intersecting or neighbouring orbits.

86. The probability of collision between an object injected into Earth orbit and the population of operational satellites is an obvious parameter to use in quantifying the hazard. However, one cannot use collision probability alone. Account must also be taken of the most probable outcome of the collision, for example impact by a 1 mm object will have a less damaging effect on an operational satellite than collision with the upper stage of a launch vehicle. Therefore, a further parameter must also be included in this assessment related to the relative kinetic energy of the impactor, in order to represent the potential damage or performance degradation that can be caused.

87. In addition to being used for regulatory means, the quantitative approach which has been proposed by the United Kingdom can be used when considering the possible contribution of an operator to a compensation fund under the "polluter pays" principle. Thus, an operator could choose between adopting debris mitigation measures in the vehicle design or operational practices, or making a greater contribution to the compensation fund. If the detrimental impact assessment is applied to all debris objects associated with a mission, an operator may choose a launch system which makes the smallest contribution to the overall collision hazard for that mission. This should encourage launch vehicle operators to adopt similar mitigation measures in their design and operational practices in order to remain attractive and competitive in the launcher market.

88. The insurance industry will be keen to indirectly protect the future missions that they will underwrite by protecting the environment in which those assets will operate. Thus, a mission making a significant contribution to the collision hazard in orbit could be subject to penalty premiums, related to the detrimental impact of the mission. This would provide financial encouragement to operators to adopt appropriate debris mitigation practices in design and operations, or at least provide them with a cost trade-off between the two. The proposed quantitative approach therefore has two aims. The first is to encourage the adoption of debris mitigation principles in mission design by illustrating the cost benefits associated with such measures. The second and ultimate objective is to maintain unlimited access to orbit for all responsible users who wish to continue to exploit the commercial, strategic and scientific potential of near-Earth space.

89. ESA's spacecraft in GSO orbit are re-orbited into graveyard orbits at the end of their operational lives. In 1984, Geos-2 was boosted into disposal orbit 230 km above the GSO. In 1991, the satellites OTS-2 and Meteosat-2 were transferred to orbits 320 and 335 km above GSO. Later, Olympus and ECS-2 were also

inserted into disposal orbits. Similarly, the French space agency CNES re-orbited its Symphonie and Telecom-1A geostationary satellites.

90. However, re-orbiting can only be considered as an interim measure. Ultimately, complete removal from orbit must be considered. Further research with regard to the end of life disposition of GSO satellites will address the location of the disposal orbits and disposition of separated apogee boost motors. Coordination between space agencies is also required in the question of co-location of satellites on the same position of the GSO. For example, at 19° west longitude, Olympus-1, TDF-1, TDF-2 and TVSat-2 have all been assigned a common window of 0.1°. Computer simulations have shown that in case of uncoordinated station-keeping of four satellites, the expected time between close encounters of 50 m or less is 0.6 years. As this level of collision probability is unacceptable, optimized control schemes have been devised which are based on using slightly different orbital parameters for the collocated satellites. With separation by different eccentricity and inclination vectors, the collision probability can be substantially reduced. The penalty is a slightly higher propellant consumption for station-keeping.

91. Since the clean-up of debris is neither technically practical nor economically feasible at the present stage of technology, the thrust of ESA action is towards preventing the creation of debris. A study has been conducted to analyze debris production processes on a representative selection of space systems and to recommend technical measures for the prevention and reduction of space debris. The outcome of this study is used for the definition of clauses in ESA's Procedures, Standards, and Specifications (PSS) documents concerned with debris preventive measures.

92. As space debris is a global problem which only can be solved by a joint effort, discussions and cooperation among space agencies and related organizations are of paramount importance. Regular coordination meetings have been held between ESA and NASA since 1987. In 1993, the Inter-Agency Space Debris Coordination Committee (IADC) was created. Its members are ESA, entities form Japan, NASA and the Russian Space Agency. The primary purpose of the IADC is to exchange information on space debris research, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities and to identify debris mitigation options. In particular, the need was recognized to develop a common database of the space debris environment which will be supported by the surveillance networks and observation facilities of all four participants.

93. To mitigate the problem of space debris, space agencies have adopted some voluntary measures. For example, the French Space Agency (CNES) together with Arianespace instituted a policy of residual fuel venting from the upper stage of Ariane launchers in case of launches into low altitude circular orbits (SPOT-2, ERS-1 and Topex/Poseidon) to prevent explosions. Since flight V59, fuel venting of the third stage has also been conducted as a routine procedure regardless of the type of the target orbit.

94. Future CNES debris mitigation policy includes the following:

- The launcher may leave in orbit a maximum of one inert object (debris) per satellite launched;

- All objects left in orbit (whatever the orbit may be) must be fully pacified to prevent any further explosions after the end of mission. Active elements such as batteries or tanks containing residual propellant must reach a fully inert state after delivering the satellites to orbit;

- Last stage separations must be clean and explosive bolts and clamps must be trapped to avoid creation of operational debris;

- Solid propellant perigee kick motors that release aluminum particles are to be avoided; and

- All other stages must naturally re-enter the atmosphere or be de-orbited.

95. United States policy requires that space activities be carried out so as to minimize orbital debris. This policy requires each programme to conduct a formal assessment of its potential to generate orbital debris. A Handbook to support implementation of the policy is being prepared by NASA to reduce the time and costs for performing such assessments and to assure consistent standards and criteria across projects. This work is being sponsored by the Office of Safety and Mission Quality at NASA Headquarters. The NASA guidelines and supporting analysis tools in the Handbook are grouped into four general areas:

- Control of debris released during normal operations;

- Control of debris collision risk during mission operations;

- Post-mission disposal of space structures; and

- Analysis of ground footprints for re-entering structures and debris.

96. The guidelines were defined to limit the risk to operating spacecraft, either directly by limiting the amount of debris placed in the space environment or indirectly by limiting the amount of non-functional mass in large objects remaining in orbit and the probability of either explosive or collisional breakups. Because removal of objects from orbit using atmospheric drag is one of the mitigation measures recommended for LEO and highly eccentric orbits, the Handbook also provides support to assess the re-entry risk.

97. The problem of space debris is also being investigated by international organizations, such as the International Astronautical Federation (IAF) and the International Academy of Astronautics (IAA). IAA recently initiated a study to be performed by experts from its Committee on Safety, Rescue and Quality. The objectives are to evaluate the need and urgency for action and to indicate ways to reduce the hazards. This document, which was approved in October 1993 as an official IAA Position Paper, recommends for immediate application the following actions:

- No deliberate breakups of spacecraft which produce debris in long-lived orbits;

- Minimization of mission-related orbits;

- Safing procedures for all rocket bodies and spacecraft which remain in orbit after completion of their mission;

- Selection of transfer orbit parameters to insure the rapid decay of transfer stages;

- Re-orbiting of geostationary satellites at end-of-life (minimum altitude increase 300-400 km);

- Separated Apogee Boost Motors used for geostationary satellites should be inserted into a disposal orbit at least 300 km above the geostationary orbit; and

- Upper stages used to move geostationary satellites from GTO to GSO should be inserted into a disposal orbit at least 300 km above the geostationary orbit and freed of residual propellant.

C. Space Debris and Nuclear Power Source Safety

98. The effect of a collision between space debris and satellites carrying nuclear power sources (NPS) in orbit is predicted to be highly destructive. This casts some doubt on the concept of "nuclear safe orbit" which in any case does not relate easily to individual or societal risk.

99. A risk-based approach, proposed by the United Kingdom, provides a quantitative alternative basis for this class of problem. Before an additional item of debris is created, it then becomes appropriate to evaluate the risk it poses over its lifetime to the whole population of orbiting items during that time and to compare the result with the cost of alternatives. Similarly, the risk from parking an NPS in a high orbit can be, in principle, evaluated taking account of existing debris. While this approach is technically demanding, it nevertheless seems conceptually straightforward.

100. In addition, it seems necessary to require that there should be no significant interference with existing missions in space and that future missions should not be jeopardized by space pollution. It is more difficult to devise quantitative limits for the deposition of debris on extra-terrestrial bodies, whether physical, radioactive or biological. Some level of consensus judgement seems to be needed on such matters.

101. The proliferation risk from NPS in space does not seem to be negligible. If a reactor or a radioisotope generator (RTG) re-enters the atmosphere, the fissionable material is likely to reach the Earth's surface more or less intact. In the case of a reactor, approximately 100 kg of highly enriched uranium-235 may be recoverable from the impact zone, a highly significant quantity in proliferation terms. Even for RTGs, the quantities may be of some significance, since the bare critical mass for plutonium-238 is around 15 kg.

102. The major accidents at Windscale, Three Mile Island and Chernobyl emphasized that physical safety provisions are not enough. It is also necessary to take account of the people in the system who in turn respond to the organizational framework in which they are placed. The recognition of this aspect of achieving the required safety standards in terrestrial nuclear safety has led to the concept of a "safety culture:" the commitment of individuals and organizations to the overriding priority of safety. In the context of NPS in outer space, much of the safety culture provision must be at the level of the country and organizations involved in the particular mission. However, in view of the high perceived risk of transnational accidents, the top layer of safety culture needs to be at an international level.

D. Remote Sensing Applications for Sustaining Biodiversity

103. The worldwide destruction of the natural environment is reducing the number of species and the amount of genetic variations within individual species. Although 1.7 million species of plants, animals and micro-organisms have been identified and classified, the total number may exceed 30 million with the great majority living in tropical forests. More than 60,000 plant species are currently in danger of extinction because of the destruction and degradation of the Earth's vegetation. The International Union of Nature Conservation (IUNC) lists three major types of threatened species: those endangered because of near-term threats to the regenerating populations, those that are vulnerable in the long-term because populations are declining in numbers, and species that are rare because their total population is small or restricted in area. There are two principal approaches for protecting and managing nature: to ensure the population of a given species is abundant and survives and conservation of natural communities in their original habitats.

104. The International Conference on the Implementation of the World Conservation Strategy held in Ottawa in 1986 examined the experiences gained and recommended that it is important to create a very reliable database and to revise and update the ecological status of existing conservation areas to maintain their biological diversity and achieve sustainable development. Therefore, there is a need for rapid methods of

developing inventories, and performing land suitability analyses. Remote sensing has emerged as a viable technology for this purpose.

105. India has its own satellite remote sensing capability with complete space and ground infrastructure. Currently, two remote sensing satellites, IRS-1A and IRS-1B (Indian Remote Sensing Satellite), equipped with Linear Imaging Self-Scanning Sensors (LISS), provide data on the Indian subcontinent on a regular basis. The designed spectral resolution allows the identification of land cover vegetation with subtle spectral differences and enhanced mapping capabilities on large scales, i.e. 1:50,000. The new IRS-1C/D series will form the second generation of operational remote sensing system with improved features such as higher resolutions, sensing capabilities in middle infrared, stereo viewing, repeated coverage of a particular area and onboard data processing. Aerial remote sensing data can also be integrated suitably with the satellite data to obtain more detailed information of the identified "hot spots".

106. In the management of wilderness areas, it is vital to have knowledge of the habitat characteristics. Such data provides knowledge about the quality and quantity of land cover, the physical setup and human interactions. The quality of habitat is generally reflected in the status of vegetation cover and its seasonal variations. Such data, however, can only be collected by ground inventories. Remote sensing can greatly help to identify such intensive ground sampling areas. Therefore, remote sensing can contribute to forest and vegetation management programmes by:

- facilitating global and regional studies otherwise not possible with conventional methods;
- complementing regional and micro-level studies by increasing accuracy and efficiency; and
- providing integrated perspective to habitat management for biodiversity conservation.

107. Data from the NOAA's Advanced Very High Resolution Radiometer (AVHRR) provides daily information on the Earth's surface in visible and infrared regions. This data can be effectively utilized to monitor vegetation cover. The normalized difference vegetation index (NDVI) is one such ratio, which is strongly correlated with vegetation parameters such as green leaf biomass and green leaf area and hence it is of considerable value for vegetation discrimination.

108. In India, a variety of NOAA-AVHRR data was used to conduct National Agricultural Drought Assessment and Monitoring studies. The studies indicate correlation of up to four weeks with rainfall and aridity anomaly. The forest cover maps generated by visual interpretation of Landsat and NOAA data show the close similarity among closed forest, open/degraded forest and non-forest areas. A technique to evaluate potential vegetation cover using the NOAA-AVHRR generated multi-date maximum vegetation index, has also been developed in India. These maps can be of immense value in the study of vegetation, its phenology, biomass and productivity. Such data can also be used in global climatic models (GCMs) for albedo, productivity as a function of carbon sink, etc.

109. Satellite data has been extensively used to delineate forest and non-forest areas in the tropical countries where up-to-date information is lacking or inaccurate with respect to spatial distribution. The studies using visual interpretation of individual images on a scale of 1:1,000,000 or 1:250,000, carried out in India by the National Remote Sensing Agency in 1983, were the first of their kind to illustrate the potential for application of remote sensing technology at the national level. Currently, Forest Survey of India, an operational agency for such tasks, is using satellite remote sensing data to biennially map and monitor India's vegetation cover on a 1:250,000 scale. The information thus generated can be used to detect relatively undisturbed forest ecosystems, identify areas undergoing rapid changes and areas afflicted with forest density change.

110. Development of range inventory and monitoring is needed to provide direction for ecological management of grasslands. It facilitates the location of resources, determination of their quantity and extent, evaluation of their condition in relation to potential production and most importantly, allows estimation of how many animals it can support. Satellite data has been used to map grasslands and evaluate their ecological status under the Department of Space's remote sensing application programme. Two studies in alpine and semiarid bioclimatic situations have been conducted by the Indian Institute of Remote Sensing. Visual interpretation of the data has helped officials map the degradation caused primarily by erosion and overgrazing. In the alpine pasture areas of the Kinnaur district, this technique has proven useful for classifying the grassland into low level pastures and pastures dominated by grass, shrubs or mixed vegetation. The digital data has also indicated clear possibilities of mapping grassland and has shown that the middle infrared and red bands are the most useful.

111. Detailed classification of vegetation types is also an important step. Vegetation types and density classes can be directly delineated from aerial photographs or high resolution satellite imagery. The relationship between vegetation, stand type and density can be established. This is important as it constitutes a major part of wild animal forage. Such a study was been conducted in India's Kanha National Park in 1991. Density stand levels also affects mobility of wildlife and is thus important in determining sites for colonies of different flora and fauna. In particular, productivity of an ecosystem is of prime importance in habitat analysis, as it determines the food value of vegetation type.

112. There are well-defined image enhancement techniques which can greatly increase the amount of information that can be visually interpreted from the image by improving the apparent contrast between features in the scene. Spectral band rationing reduces the topographical effect by more than a factor of six on radiance data sets. Satellite digital data has been used to stratify forests based on their type, species composition and density. Although digital classification has proved to be a more accurate and objective methodology for classifying land cover features, the changes brought about by the phenological behaviour of vegetation types and illumination conditions make the methodology at times scene dependent. The former aspect can be taken into account by selecting appropriate season data when vegetation type canopies behave true to their nature.

113. Northeastern India is endowed with extremely diverse fauna, flora and people and it is among those regions of the world where shifting agriculture has been the predominant form of land use for centuries. Despite continued criticism and an effort to ban the practice, about 3 million hectares of land is currently under cultivation in this humid, tropical region. This influences the moist deciduous forest in the Himalayan foot hills and the wet evergreen forest at mid-level elevations up to the temperate habitats in eastern Himalaya in Arunachal Pradesh. Comparative analysis of vegetation maps of Chandaka Wildlife Sanctuary (Orissa), prepared by aerial photographs from 1975 and IRS satellite data from 1989, illustrate changes in the vegetation pattern and increases in the mining and agriculture areas within the sanctuary. After enforcement of the wildlife conservation act, bamboo has been found to extend into the valleys and side slopes of the sanctuary area. Thus, this technique has the potential to monitor retrogressing and successional changes in the habitat condition.

114. Acquisition of detailed stock information is a prerequisite for the development of habitat management processes. The stock maps depict forest type, density, encroachments, cultivation patches, regeneration status and provide an idea about available resources and other ecological details in the minimum management units, viz., compartments. The efforts involved for the preparation of such stock maps through conventional ground survey methods are time consuming and strenuous. Work carried out at the Space Application Centre in Ahmedabad, India, in 1989 demonstrated the uses of visual interpretation methodology to update stock maps from high resolution Salyut-7 MKF-6 multi-band photographs and IRS satellite LISS data. The information content on enlarged images (1:15,840 scale) might not be commensurate, but the available information on remote sensing data is definitely more detailed than that shown on the stock maps. E.g. the boundaries of

forest types, drainage encroachment and cultivation patches are much more reliable. Further processing through supervised classification and vegetation indexing of IRS-LISS data, overlaid with compartment boundaries, make such products extremely useful for practical field management. Recent analysis of survey requirements for habitat management indicates that stock map requirements may be accomplished only with a scale of 1:25,000.

115. Wetland areas are probably the most endangered habitats in the tropics since they are systematically reclaimed for agricultural purposes. There are two basic remote sensing approaches for monitoring wetlands: defining existing water sources and assessing water resources necessary to sustain the wildlife habitat. Aerial photographs, because of their high resolution, are excellent for identifying water holes, but temporal analysis is not cost-effective compared to satellite data. An estimate of the conservation value of the wetlands in Etawah and Mainpuri districts has been conducted at the Centre for Ornithology and Natural History in India. The major goal of the study was to determine whether the combination of satellite remote sensing and ground data would enable classification of wetlands on an ecological basis. The study focused on mapping of grasslands and three taxa viz., aquatic flora, fish and birds. Based on the spatial characteristics of the wetlands, surrounding land use, bird population diversity and density and plant community distribution, 18 wetlands areas have been identified for conservation. This study is based on geographic information system (GIS) data.

116. The natural habitats of a wide variety of species are being fragmented through development. Particularly in the forest areas managed for wildlife, there should be a network of patches of old growth forest joined by dispersed corridors of similar structure and composition. In 1990, space remote sensing data were used to collect vegetation cover information in the Corbett National Park and Rajaji National Park in India. These are important conservation areas in similar biogeographic locations. These national parks had continuous forested tracts allowing free movement of elephants in the region. However, during recent years these patches have been fragmented. The corridor which allowed free movement is used sparingly today, but in the process, elephant herds come in contact with human made land covers and conflict is often reported. Remote sensing data at various levels have helped to analyze the various land use and land cover units. The regions's socioeconomic situation is being kept in mind to restore the lost corridor. Similar applications have been reported in the Yala National Park border zone in southeastern Sri Lanka.

117. The high rate of deforestation and habitat fragmentation in tropical regions are the primary cause of the present increased rate of reduction in regional biodiversity. Remote sensing technology must play a key role in surveying, assessing the resources and recording the habitat changes. GIS technology can store, retrieve and analyze a database of collated ground level data and spatial thematic maps. The present state of the art can meet most of the habitat management requirements at various levels. Micro-level management needs, however, are only partially met from aerial photographs. The following strategies seem to be appropriate for managing forest resources in the tropics:

- Landscapes should be subdivided into manageable and meaningful regions with a variation of life zone systems. This would help in proper forest land use planning.

- Databases should be created at various levels (global, regional and at the micro-level) in a suitable format which can be accessed.

- Within each biogeographic region, pilot test sites should be selected and surveyed. Updated and more detailed inventories (from remote sensing data, if possible) can be stored in a retrieval format. There should be sites representing the entire region, sites where rapid changes are occurring (e.g. deforestation) or sites which are exceptionally productive.

- Environmental indexes from detailed ecosystem analysis should be developed in order to understand the relevant ecological properties.

- Abnormally rapid degradation should be mitigated by critical habitat management methods using available accurate and true data about existing resources.

E. Hubble Space Telescope Repair and First Scientific Results

118. The Hubble Space Telescope (HST) is a collaborative project between NASA and ESA. Based on the old concepts of an orbiting astronomical observatory, as described by Oberth as early as 1923 and by Spitzer in 1946, the HST provides astronomers access to the ultraviolet, optical and near infrared parts of the electromagnetic spectrum. When launched in 1990, after considerable delay because of the Challenger accident, the HST had a complement of five scientific instruments: two cameras, two spectrographs, and one photometer. Light is collected by a mirror 2.4 m in diameter. Within several weeks after launch it turned out that the mirror was polished to the wrong geometric shape, which resulted in images showing spherical aberration, i.e. much less than the expected amount of energy was collected in the central peak of the images.

119. HST was designed to be refurbished in orbit, as it was unlikely that all the components of this highly sophisticated space observatory would remain operational throughout the planned 15-year lifetime of the spacecraft. Thus, several of the malfunctions which occurred between 1990 and 1993, (most of them were temporarily corrected through the use of redundant components), had actually been anticipated. However, the main mirror could obviously not be exchanged in orbit. Another component, which caused serious operational problems because of thermally induced jitter, the solar panels, were in-orbit replaceable, but replacement panels had to be manufactured. It was also fortunate that even before the initial launch of HST, preparations had been made to replace the main camera on the telescope.

120. HST provided valuable information even prior to the repair mission. For example, it still provided access to the ultraviolet spectrum, retained the high resolution imaging capability, and was available in a sustained and consistent manner for synoptic investigations. However, several key capabilities were lost due to the optical flaw: the ability to detect very faint objects was lost, as was the ability to detect objects and structures near very bright sources. The ability to do accurate flux (energy) measurements was also severely impaired. These restrictions implied the loss of major science programmes, some of which had been driving reasons for building the HST: determination of the cosmological distance scale, and investigation of the physical processes in active galaxies and quasars.

121. Immediately after the optical flaw was discovered, and its nature and source had been identified, a study panel was convened by Riccardo Giacconi, then the director of the Space Telescope Science Institute. The panel brought together scientists, engineers, project managers, astronauts and industry officials. The panel sketched out a multitude of potential corrective measures, and finally recommended the implementation of a particular one: the Corrective Optics Space Telescope Axial Replacement (COSTAR). COSTAR was designed to take the place of one of the science instruments, extract an optical bench, and deploy arms carrying the corrective optics in front of the three axial instruments. This concept combined operational feasibility with minimum risk.

122. The First HST Servicing Mission was supposed to perform the following tasks: replace failed gyroscopes and drive electronics, change spent electrical fuses, replace the solar arrays, install a new wide field/planetary camera, install new magnetometers, install COSTAR, upgrade the on-board computer, install new solar array drive electronics, install a repair kit on the Goddard High Resolution Spectrograph, and finally re-boost the HST to a higher orbit. This represented a very ambitious mission profile, which the

astronauts assigned to the mission, through dedication, skill, and extended training in simulated space environments, executed with admirable success.

123. It took several weeks to transition the HST from pre-COSTAR to post-COSTAR operations. This was itself a carefully orchestrated activity designed to optimize the performance of all instruments. However, during this process it became obvious that the servicing mission had been a tremendous success. Astronomers now have available an excellent tool which is capable of answering many of the questions which modern astronomy poses.

F. Adverse Environmental Impacts on Astronomy

124. There is no doubt that the spectacular developments in science and technology since the 1950s have led to unprecedented changes in industry, commerce, communications and entertainment. Astronomers have been the beneficiaries of this technological change through enhanced sensitivity of detectors, novel telescope designs and the opportunity to not only observe from space but to fly-by the other planets of the solar system. The changes in perception of the solar system are a magnificent testament to how little was understood about planets before such missions were possible and a salutary reminder of how much remains to be understood so close to the Earth.

125. While bestowing powerful gifts upon the astronomical community, the technological age has also brought unprecedented levels of noise – weak cosmic signals are being progressively lost in a cacophony of human generated, locally transmitted signals at all electromagnetic wavelengths. Even outer space itself is being used to bombard our radiotelescopes with signals from which there can be no escape. Humanity's use of space is under threat from increasing amounts of debris left over from former missions and that debris is becoming an increasing menace to ground-based observations.

126. Radio astronomy has developed to a stage of great sophistication and sensitivity which now matches and sometimes exceeds the spatial resolution of optical astronomy. However, due to its extreme sensitivity, radio astronomy is very vulnerable. A mobile phone on the Moon would be one of the three brightest cosmic radio sources. Every piece of electrical equipment from "on/off" switches upwards is a source of radio noise. Unlike optical telescopes, radio telescopes have sidelobe responses which can pick up transmissions from sources not in the line of sight of the telescope. Powerful radio transmissions are beamed at the Earth from space and from aircraft. Fortunately, the International Telecommunications Union (ITU), which regulates the use of the frequency spectrum , has allocated 2 per cent of that spectrum (up to 275GHz) to radio astronomy. As commercial users move to higher frequencies, new allocation of frequency intervals will be made. However, at these high frequencies there are the spectral lines of interstellar molecular species. Sufficient bandwidth must be allowed for continued astronomical investigations.

127. Despite the allocation of bandwidths reserved for radio astronomy and the internationally binding nature of ITU agreements, there are daily violations of those reserved bands. Some violations arise through ignorance or disregard of ITU regulations, others occur inadvertently, e.g. re-tuning an airborne radio transmitter while in the primary beam or a sidelobe of a radio telescope. Some violations arise from inadequate standards of electronic engineering that permit leakage or drift of transmitted power into the reserved band, or through the generation of harmonic frequencies which fall into a reserved band. The GLONASS navigation satellites which use spread frequency transmissions, made observation of the important astrophysical maser line at 1612 MHz almost impossible because they utilized this frequency as their central transmitting frequency. Fortunately, this unforeseen consequence of a shared band is now in the course of resolution in the favour of astronomers through the considerable good will of GLONASS authorities. However, astronomers must look forward to 1999 before the last unmodified satellite is phased-out.

128. Like every other activity in space, space astronomy is threatened by the growing threat of space debris. It is only a matter of time before a major operational satellite is destroyed by such a collision. Debris also has other effects. The number of debris trails on deep sky astronomical plates has reached the point where 1 in 3 plates now carries one or more debris trails. Some plates are completely degraded for any scientific purpose by the sheer number of debris trails. At 7,000 pieces of trackable debris, it means that on average, there is one piece of debris every 6 square degrees of sky. A piece of debris crossing the field of view during photometric observations ruins the data and, if the trail is bright, may cause irreparable damage to sensitive detectors. The chance of a piece of debris passing through an area of sky 1 square arc second in area during standard exposure is in excess of one part in 10^{-8}, but such an unlikely event has already taken place and is documented.

129. As if the current situation with space debris is not bad enough, there have been some proposals that make the present situation look satisfactory. In recent years there have been a number of suggestions for the launch of large solar reflectors to mark particular events – e.g. the centenary of the Eiffel tower, the Olympic Games in 1996. To be seen on Earth, most of these proposals require a perceived brightness of the reflector to be that of the full Moon. Clearly, current proposals may not represent a significant threat to astronomy, but inevitable development could lead to the abandonment of any ground-based astronomy. Astronomical observation of the faintest cosmic sources at optical wavelengths can only be carried out in the "dark of the Moon", i.e. two weeks each month either side of new Moon when the Moon is in the sky for a short period just after sunset or before sunrise. To allow the sky to become populated with "artificial full Moons" would not only put an end to deep sky astronomy, but would also severely compromise many other astronomical observations. Even small solar reflectors inadvertently reflecting a beam across an unsuspecting observatory could wreak considerable havoc on sensitive instruments.

130. The astronomical community views such developments with unrelieved dismay. Solar reflectors, space debris proliferation and pressure on the radio spectrum together would mean the end of ground-based astronomy as a serious science.

131. However, the astronomical community is using all the means at its disposal to inform responsible institutions about these threats of demise of a science whose age can be measured in millennia. Fortunately, there is support for astronomical science, e.g. new outdoor lighting design is available to minimize upward light escape, the GLONASS transmission scheme is going to be redesigned. The ITU still reserves frequency bands for radio astronomy and the organizers of the 1996 Olympics in Atlanta turned down a proposal for solar reflector as a means of advertising the games. However, in the absence of firm international agreements, too much depends on local bilateral agreements and on the efforts of a few dedicated people.

G. International Cooperation in Space Research

132. Contrary to what laymen may think about the use of weightlessness in space, it allows for investigations of subtle effects of general interest, hidden on the Earth by the all-dashing impact of gravity. One of the main directions of German space research activities over the last decade has focused on the unique scientific capabilities of the European contribution to the United States Shuttle system – the Spacelab.

133. The first dedicated Spacelab D-1 mission was successfully completed in 1985. The second German Spacelab mission, D-2, was launched on 26 April 1993 on the Space Shuttle Columbia. After 10 days in orbit at about 300 km altitude, 160 revolutions around the Earth and 6.7 million flight kilometres, the D-2 mission successfully ended on 6 May 1993. Sixty-two of the 89 scientific experiments carried on the mission were developed in Germany, 7 were from France, 4 each were from Denmark and Japan, 3 were from Italy, 2 each from the Netherlands, Belgium and the United States, and 1 each from Sweden, Spain, and Switzerland.

134. The D-2 mission was a truly international mission covering all scientific topics, including: materials science (37 experiments), biology (18), human physiology (24), technology (2), Earth observation (2), astronomy (1), amateur radio (1) and even experimental sub-satellites (4).

135. Two German astronauts were selected from 1,799 applicants to fly on the mission. After a comprehensive selection process focusing on psychological, concentration, and medical tests, training commenced in March 1988 and continued for five years. Basic training included areas such as mental skills (private pilot license, jet flying on Alpha-Jet and Boeing 737 aircraft, familiarization with conditions in space (parabolic flights, scuba diving), sports, orbital mechanics, astronomy and astrophysics, general introduction into space-relevant scientific areas, scientific research on personal topics, psychological training, training in public appearances, etc. Apart from the regular astronaut training, D-2-related training included extensive introductions into all D-2 experiments, workshops, manual training of the flight experiments, training for off-nominal situations, mission simulations (both stand-alone and joint-integrated simulations with NASA), and finally NASA Shuttle training (in particular the emergency egress training) from 1 August 1992 to mission launch.

136. Brazilian space activities, as coordinated by the Brazilian National Institute for Space Research (INPE) will significantly expand in the near future. Oriented mainly to satellite communications and remote sensing, up to ten spacecraft are already planned for launches from Cape Canaveral (United States), Kourou (French Guiana), Alcantara (Brazil) and the Shanx/Talyuan complex (China).

137. The environmental data collection satellite SCD-1 (Satellite de Coleta de Dados) was successfully launched by the third Pegasus vehicle on 9 February 1993 into a low-Earth orbit with an inclination of 25° in order to provide adequate coverage of Brazil and particularly the Amazon region. SCD-2 will be ready for launch by late 1994 into a similar orbit. Two identical geostationary communication satellites Brazilsat-B1 and B2 are also scheduled for launch in 1994 by Ariane 4 launchers.

138. Based on the SCD experience, a more complex remote sensing satellite, SSR-1, equipped with a small CCD camera is being developed by INPE. It should be able to transmit 200 m resolution images in two visible spectral bands. It should be launched in 1996 with the indigenous VLS launcher from Alcantara (in the Brazilian state of Maranhao) into sun-synchronous polar orbit at 640 km altitude. An identical satellite, SSR-2 will be ready for a Brazilian launch in 1996-97. The first remote sensing satellite CBERS-1 (China-Brazil Earth Resources Satellite) developed through a cooperative Brazilian-Chinese programme, is scheduled for launch by the Long March 4A rocket in 1995-96. The optical payload of the 1,400 kg spacecraft will consist of three imaging sensors: Wide-Field imager, High-resolution CCD Camera (producing 20 m resolution images) and Infrared Multispectral Scanner. It will also carry a data collection system. CBERS-2, fully integrated in Brazil, will be ready for placement into orbit by a Chinese launcher in 1998-99.

139. In the field of small scientific satellites, Brazil is actively cooperating with Argentina in preparation of SAC-B (Scientific Argentinean Satellite). The satellite and its components are being tested at INPE's integration and test laboratory which is also available for industrial applications. A solar astronomy spacecraft is being developed jointly with Italy and the United States. It will monitor solar eruptions, high energy X-rays and gamma ray bursts. The satellite is scheduled for launch on a Pegasus rocket in June 1995.

140. Space research activities have continued in the former Czechoslovakia where small scientific satellites weighing about 50 kg have been developed for the Magnetosphere-Ionosphere (MAGION) research programme. The first MAGION satellite (weighing only 15 kg) was launched on 24 October 1978 to make simultaneous measurements with Intercosmos-18. Two more sophisticated satellites were launched into high-inclination and low-eccentricity orbits (altitude 500-3200 km) as a part of the mother-daughter active space experiment missions: ACTIVE (MAGION-2, launched on 28 September 1989) and APEX (MAGION-3, launched on 18 December 1991). The payload of the subsatellites was used as an independent diagnostic

package. During the periods when no active experiments were switched on, the satellites and subsatellites were used for simultaneous two-point measurement of natural phenomena.

141. Two other MAGION-type subsatellites of similar mechanical design and electrical subsystems have been designed for the INTERBALL mission aimed at studying physical mechanisms of solar wind energy accumulation in the magnetosphere and dissipation of the energy in the auroral regions during magnetic substorms.

142. The INTERBALL mission consists of two pairs of spacecraft, situated in different orbits. On pair, the "Auroral Probe" with an apogee of about 20,000 km; the other one, the "Tail Probe", with an apogee of 200,000 km. Both orbits should have perigee heights of about 500 km and inclinations of 65°. Each pair of satellites consists of the main spacecraft of the PROGNOZ series, accompanied by a subsatellite of the MAGION type. The scientific objectives for the subsatellites are to separate time and space variations, to study spatial correlations and fine structures in the ionosphere and magnetosphere. Separation of the subsatellites will be controlled by small thrusters. The scientific payload of the subsatellites includes instruments for measurement of magnetic and electric fields, plasma waves, cold and hot plasmas and energetic particles. The INTERBALL subsatellite payload and subsystems have been developed and manufactured through an international cooperative effort involving Austria, the Czech Republic, France, Germany, Poland, Slovakia, Romania and the Russian Federation.

143. During the last few years, there has been a trend to concentrating the types of satellite orbits used for practical purposes into two separate categories: the distant GSO and the closer LEO. Despite the difference in the distance, satellite users need increased positional accuracy to accomplish their intended mission. Surprisingly, this turned out to be easier in the case of the distant GSO than in LEO. The reason is that perturbing forces affecting the motion of the satellite are much better defined for GSO than for LEO. One of the most disturbing and unstable forces is atmospheric drag and lift.

144. To develop a good model of satellite motion in the upper atmosphere, one must first have precise experimental data about atmospheric parameters and their spatial and temporal changes. An instrument which can measure all disturbing forces of non-gravitational origin (including atmospheric drag and lift) acting on a satellite is called an accelerometer, or a microaccelerometer if it is extremely sensitive. In principle, it measures a relative motion of two objects on the same orbit, i.e. the centres of mass of both orbits move on the same space trajectory, whereas one body is subjected to the atmospheric acceleration and the other one is shielded from that effect. In practice, an accelerometer consists of a proof-mass (a small ball or cube) located inside a cavity and the change of the distance of a proof-mass from external body is precisely measured. Preferably, this instrument should be situated in the center of the mass of the satellite to eliminate other effects.

145. Such types of accelerometers, capable of measuring acceleration of the order of 10^{-5} to 10^{-10} $m.s^{-2}$ have already been constructed and some of them have even been placed into orbit (French Cactus, Supercactus, Gradio). At the Astronomical Institute of the Czech Academy of Sciences, an accelerometer with a cubic proof-mass is now under development. The device is called "Macek" and was tested in orbit in June 1992 on board the recoverable Resource-F satellite. The Russian capsule returned softly to the Earth, and the mechanical condition of the instrument was checked. During this technological experiment, practical information about the reliability of the construction was obtained with very encouraging and promising results. The main drawback of this experiment was an inconvenient location of the microaccelerometer on the main satellite body. Therefore, centrifugal force due to satellite rotation caused profound disturbances which "masked" most of the atmospheric effects.

146. The ultimate goal is to place the Macek accelerometer on a dedicated satellite where it will be possible to get precise data on the atmospheric density distribution and variation. The vehicle for achieving this goal

is the Central European Satellite for Advanced Research (CESAR) project, undertaken through a cooperative programme among Austria, the Czech Republic, Hungary, Italy and Poland. The project is now in the final stage of its Phase A with agreed details of instrumentation, telemetric systems and orbit selection. The launch of this satellite for the study of the physical properties of the near-Earth environment is now scheduled for 1997.

Appendix

LIST OF SCIENTIFIC AND TECHNICAL PRESENTATIONS

I. SYMPOSIUM ON SPACE APPLICATIONS FOR DISASTER PREVENTION, WARNING, MITIGATION AND RELIEF, ORGANIZED BY COSPAR AND IAF

The Symposium was co-chaired by Mr. L. M. G. Enomoto, representing IAF and Mr. S. Bauer, representing COSPAR (first session) and Mr. A. Azcarraga, President of the IAF and Mr. H. Stoewer, representing COSPAR (second session). Mr. R. Gibson of the IAF was the Rapporteur for both sessions of the symposium.

"Space Contributions," Mr. L. Emiliani, Director, Observation of the Earth and its Environment, European Space Agency.

"Space Observations for Understanding (and Predicting?) Earthquakes and Volcanic Eruptions," Mr. J.L. Le Mouël, Director, L'Institut de Physique du Globe de Paris, France.

"Remote Sensing of Severe Weather Events," Mr. W. P. Menzel, Space Science and Engineering Center, University of Wisconsin, United States.

"Desertification and Land Degradation," Mr. Zheng Du, Director, Institute of Geography, Chinese Academy of Sciences, China.

"Floods and Droughts," Mr. U. R. Rao, Chairman, Indian Space Research Organization, India.

"Global Food Security," Mr. F. L. Snijders, Remote Sensing Centre, Food and Agriculture Organization of the United Nations.

"GEOWARN," Mr. E. Slachmuylders, ISU/ESA-ESTEC, and Mr. W. Neubert, Technische Universität, Vienna, Austria.

"Summary of the Symposium," Mr. R. Gibson, International Astronautical Federation.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

"Hubble Space Telescope Servicing Mission and First Scientific Results," Mr. K. Bowersox, Astronaut, NASA, United States, and Mr. R. Albrecht, European Southern Observatory, European Space Agency.

"Remote Sensing Applications for Sustaining Bio-diversity," Mr. M. G. Chandrasekhar, Indian Space Research Organization, India.

"Brazil in Space," Mr. R. da Cunha, Instituto Nacional de Pesquisas Espaciais, Brazil.

"Use of Nuclear Power Sources in Space," Mr. B. Wade, Atomic Energy Agency, United Kingdom.

"A Review of Scientific and Technical Aspects of Space Debris," Mr. D. Rex, Technical University of Braunschweig, Germany.

"Orbital Debris,", Mr. J. P. Loftus, Jr., NASA, United States.

"Space Debris Research in India," Mr. K. Sridharamurthi, India.

"CNES and Space Debris Issue," Mr. H. Laporte-Weywada, Directorate of Launchers, Centre National d'Etudes Spatiales, France.

"Space Debris - Research in ESA," Mr. W. Flury, ESOC, European Space Agency.

"Space Debris - United Kingdom Position," Mr. R. Crowther, Defence Research Agency, Farnborough, United Kingdom.

"Flight of Spacelab D-2," Mr. U. Walter, Astronaut, German Aerospace Research Establishment DRL, Germany.

"Remote Sensing and SPOT Image," Mr. C. Jung, SPOT Image, France.

"Experiment MACEK as a Part of the Project CESAR," Mr. L. Sehnal, Astronomical Institute, Czech Academy of Sciences, Czech Republic.

"INTERBALL Subsatellites", Mr. P. Třiska, Geophysical Institute, Czech Academy of Sciences, Czech Republic.

"Adverse Environmental Impacts on Astronomy," Mr. D. McNally, International Astronomical Union.